9.27.04, 1.30 - 5.30 pm - Session One – Earth

Ed Viesturs, Penny Boston, Dale Andersen, Nathalie Cabrol, Bill Stone, David Roberts

Tigerfish®
Transcribing·Editing

203 Columbus Avenue · San Francisco 94133
toll-free 877-TIGERFISH
www.tigerfish.com

9.27.04, 1.30 - 5.30 pm - Session One – Earth

Ed Viesturs, Penny Boston, Dale Andersen, Nathalie Cabrol, Bill Stone, David Roberts

Chris McKay: We're going to open up the discussion. We very much want to have a discussion. I see out in the audience many explorers and program managers, which is sort of like exploration, who have a lot of experience in risk, and understanding risk, and achieving objectives. So we really want to use the panel as a catalyst to start a discussion to try to bring in some of those perspectives that you guys have out in the audience.

Earth, what do we mean by earth? There are three panels, as you know, earth, sea, and space. Earth, we're going to cover mountains, caves, the polar regions, both poles. You're going to see that the panel has a real depth and richness of experience in exploring all of these environments. And what I'll do is ask the panelists to each talk for about ten minutes to just introduce themselves and their work, and then we'll have some discussion within the panel, and then quickly have discussion with the audience and go from there. What I'll do is, I'll introduce the panelists as they speak, so we'll start on that end with Dale Anderson, and then we'll proceed down here and end with Dave Roberts.

Dale is jointly at McGill University, the SETI Institute, and NASA Ames. I've known Dale for many years, worked with him in the Polar Regions. I think of him as NASA Ames' dive master. Any time we have to go underwater, particularly if the water is covered with 15 feet of ice, Dale is the person we talk to. Get him in there first, then if it's safe, the rest of us follow.

[Laughter]

So Dale, without further introduction, can you go ahead?

Dale Anderson: Okay, thanks, Chris. Well, what I'm going to do is, I'm going to start talking about my experiences in both the Antarctic and in the Arctic, and I'll focus more on the Antarctic; right now it's a little bit more exciting. And as soon as we get the—there we go.

We started back in the late '70s working at some of the lakes that are in the [unintelligible] valley. And this is one of the largest ice-free regions that exist there. And there is a series of lakes with very, very thick ice cover, and nobody had ever probed these lake before, and looked at them in depth, other than just taking some drills and popping small holes in them, and sort of taking a soda straw approach. We wanted to look at them in little different fashion. So I started thinking about this symposium, I started categorizing the kinds of risks that we were involved with over this period of time. And for us it really came down to again the mission risk, was the success of our expedition in general. And then we've got personal risk, which I've divided into transportation to and from the research site, which we have very little control over. We take usually large ski aircraft to get down to McMurto Sound, and then up north to get to Twin Otter. And then to get into our remote field sites, we'll take helicopters, or in some cases on some of the expeditions I've been on , we've taken Soviet icebreakers around the continent, and then taken helicopters inland and have been dropped off.

We don't have much control over what happens during those times. We're there for the ride and hopefully it makes it. And obviously sometimes the weather and the conditions can get pretty bad along those lines as well.

Then we have living and working actually in these remote environments. And we have to learn how to do both of those things—we have to learn how to live effectively. And that takes quite a bit of effort, if you're going to spend lengthy periods of time in these remote settings.

And then it's not just living, but you also have to accomplish some work, and developing the skills that require you to do that work is also something that we've had to overcome over the years.

And then there is also the scientific credibility from a personal standpoint. We can put all the effort into going to these regions to do the studies, and if we get there, and the weather is too bad, or if the equipment doesn't work, or we've forgotten something really important, just too bad. And then we come back with nothing but our hands in our pockets, and say, well, we had some good times. And then the program managers yell at us and don't give us any more money.

And of course the currency, the ultimate currency, would be scientific publications. And if you don't get those scientific publications, then you don't get to go back down and do that kind of work again.

And then of course there is the family setting. And it's always difficult to be away for these long periods of time, especially when you are in a hostile environment. Your family doesn't know from a day- to-day perspective, you know, just wandering around in the snow or if you're drowning underwater or whatever is going on. So that's one of those long arms that's always reaching out to you.

Over time, we've really had poor communication. And it's something that has only change in the last five or six years, really, where we can pretty much have global communication on an instantaneous basis. It used to be that we just didn't have any period, it took weeks or something to get through.

And then of course there's risk to others, or assigned risk. And if I'm a leader in an expedition, and I can send people out to do work, my level of risk assessment is going to be -- or the way I go about evaluating that is different than what I would expect for somebody else depending on their level of training or what their experience is.

And then of course for a program manager that perspective might be completely different. If they've never been in a field situation similar to that, or if they have any kind of mountaineering or diving experience, or some other kind of experience that they understand personal risk from that standpoint. But it's one of those values to have those kind of people in those positions.

Again, these are some of the kinds of transportation risks that I've been involved with. Large aircraft, large icebreakers, even [Hoglands], which are track vehicles that we can take across the ice shelves among the continental ice. And then helicopters. And all of those have different types of risk associated with them. And then in some cases, like the Hoglands, we drive those personally, so then we have to be able to understand how to drive a vehicle like that, keep it out of crevasses, and understand what to do when it breaks down, which it invariably will.

This is an example of a part of the dry valley. So you can see, a lot of the ice is not in the valley itself. You have the continental ice flowing through, and you have a barrier that essentially keeps a lot of this from going into the valley. The evaporation highly exceeds the precipitation, so it's quite dry.

But you can see some of these small features in between the glaciers are actually lakes. Such as this one, this is Lake [Hore], where we spent quite a bit of time studying the lake ecosystem itself. Now these lakes are permanently covered in ice, and the ice thickness ranges from about 3-4 meters up to 6 meters.

In earlier years about the only way people studied them was to go out and drill a small hole through it, and then take water samples and take some other measurements. But nobody ever really asked the question, what's going on at the bottom? Because most people thought the light levels were so low that there wouldn't be anything on the bottom.

Well, a few years later we decided to open these lakes up with a bigger hole so that we could go down and look. And I guess for some reason we weren't smart enough, or I guess at that time underwater cameras were still a hassle to get ahold of, and it was just as easy to go put us in the water as it was to take a little camera and drop it down the hole. But that wouldn't have had nearly the fun factor, either, I guess.

So anyway we developed a system that allowed us to melt holes through this ice. And essentially we take a copper coil and just put hot [unintelligible] solution through it, let it melt down the ice. And you can see that we can move in and out of that ice cover, as we're melting it. It's like a tunnel, of course, a water tunnel.

And then we suit up and we jump in. Now originally we started out in wet suits and double hose regulators, which is kind of ancient history. And over the years, obviously, that wasn't the best solution, because then you've got to deal with a really cold wet suit once you get out if it's minus 30. It's not too comfortable to take a wet suit off in those conditions.

So we went to dry suits and whole facemasks, and you can see that we're on tether, because once you go in, you've got one way in and one way out.

Now why did we go to these places? That to me was the biggest payoff. We could have gone down there. Actually we did have some of the program managers who were associated with the project tell us, just before we were getting ready to go in for the first time, that we were just going to find a bunch of rocks, and that we'd wasted everybody's time and money.

So what we found was a really lush, luxuriant microbial ecosystem that had never been seen before. And as it turns out, these tunnels that we make through the ice are just like tunnels back through time, 600 million years to 3.5 billion years ago. And this gives us a glimpse of early earth, and perhaps of early Mars. If lakes existed on Mars, they would possibly have been ice covered, and possibly have microbial communities similar to what we see in the dry valley. And these are two of these kinds of microbial mass communities. Very very prolific.

And of course our work there is very dependent on the training that we received. We have to be very very safe. We're diving in extremely remote areas where we don't have the opportunity, at least at that time in this particular area, we didn't have the opportunity to get back to a recompression chamber. The closest one would have been in New Zealand, and that's of course after a helicopter possibly came out and picked you up and dragged you back to McMurta, and put you on a 141 back to New Zealand.

When we were in other situations, we didn't have that option at all. The nearest chamber was probably several months away. And we worked everywhere from about 40 meters up to the water columns. We have to be very very careful about the dives that we go to, and the kind of diving that we're doing. This is looking up through about six meters of ice, and you can see that one tether that takes you back to the surface is so very important. So it's kind of like follow the light. And again, here we are coming to the surface. And it's actually very very fun diving. It's very exciting to go into these lakes.

Now, we also started a program a number of years ago. Because we can only go so far out on our leash underwater, we really are restricted to the amount of material we can see. So we started a telepresent project where we started using remotely operated vehicles -- actually [Toby Earl] loaned us the first ROV that was used down in the Antarctic in one of these lakes. This was a newer generation of that. A lot of the algorithms that we put on for the particular PROV right here were actually utilized later on in our Pathfinder. Some of guys in the Intelligence Mechanisms Group at Ames worked very closely with us on that. Anyway, that was a very good means of getting out and away from that dipole, for example, and getting into working with other communities. We also had to learn to operate this kind of equipment in those environments.

Now we just don't follow the microbial communities underwater. We also follow them wherever we can find them. That includes on top of the glaciers, like in this shot. We then have to pick up ice climbing skills and some general mountaineering skills when we want to go up into the alpine areas. So, it's a real skill mix to work in these kinds of regions.

On a more programmatic kind of deal, in 1991-1992, I had the opportunity, along with Jim Rice who is here in the audience and Peter Dorn who is in Chicago, Illinois, to go to the Bunger Hills, another tri-free area in the Antarctic with the Soviets. That was a joint expedition between our two space programs through the Space Medicine and Biology Working Group, and it was part of the Exobiology Implementation Team that allowed us to get together with their exobiologists. So, three of us joined eight Russians. We traveled two months around the Antarctic continent by icebreaker. We got dropped off by helicopter for the next four-and-a-half months in extremely remote settings with quite a few cultural and language barriers. To be honest, the expedition took place at the very last minute because of the way programmatics work and the way permissions go and because the dialogue between the Soviets and the US at the time was kind of slow. We didn't find out that we were actually going until four weeks before we left, so we had to buy everything, ship everything and get everything down to South America. Hopefully, it was all there when it got onto the ship when we got there. We actually didn't open up our boxes until we literally got to the Bunger Hills, and the last helicopter left.

It was a pretty quaint setting. We spent some time in some of the huts that they had there, but we also spent quite a few months sleeping in tents on the ground in the rocks. There was a great deal of wind. This is an area that is prone to katabatics. You can see a small little windbreak that I made here in one big storm that we had. You can see one of the Russians had a series of panels about our expedition, and this is one of the panels that they had. You can see the Grim Reaper trying to grab me during the windstorm there. So we had quite a few difficulties while we were there, but we also had to accomplish some work. All in all, it was a very successful mission, both scientifically and culturally. It was very culturally enriching to all of us, and it showed at that time, even though it wasn't a space project per se, the two space programs were working closely together in an isolated, Mars-analog environment.

Now more recently I have shifted poles, and we are now working in the Canadian high Arctic. You can see the setting is not altogether that different. It is very, very glaciated. There are large Alpine glaciers and [unintelligible] glaciers along with large ice sheets. We're studying a series of perennial springs in this region. These are the highest latitude perennial springs in the world, along with the [unintelligible] over in [unintelligible] at [intelligible]. This is a great Mars analog. There were springs on Mars coming up through thick continuous permafrost. This is where we would go to see these. Again, this is a very remote setting to which we take Twin Otters and helicopters, are dropped off and were left for a few weeks or months.

It's a little shorter logistics train up to the Arctic, so we can get back and forth much easier. Nevertheless, while we're there, we are actually a little more isolated at times than we are in the McMurta Dry Valley area because [unintelligible] so good. I will just cut it off here.

Chris McKay: Thanks, Dale. Let's give Dale a hand, and then we'll go to the next speaker.

[Applause]

Chris McKay: And we'll save questions, and do the panel all at once. I just want to comment that Dale's partitioning of risk into Mission Risk, Personal Risk, and Assigned Risk is a nice partitioning. Let's hold that thought for the discussion.

The next speaker is Ed Viesturs. I first met Ed at the Tech Museum here in San Jose at the premiere of their Imax theater. The film they were showing for this premiere was Everest, and it starred Ed climbing Everest without any oxygen. Having only been up to 19,000 feet, I know that's incredible. I could barely breathe at that altitude. I think he actually doesn't have lungs and blood. It's all mechanical . . .

[Laughter]

But he probably sets off the metal detectors on the plane. So, anyway, Ed, you're up.

Ed Viesturs: Hi, everybody. We'll go to the next slide. I've been climbing now for 27 years, and hopefully I've done it the right way. I started by climbing small peaks and then aspired to climb higher and higher peaks. As I was going higher, I eventually realized that what I liked about mountaineering was the extreme challenge and how difficult it was and also, the beauty of climbing these mountains without oxygen -- the pure way -- the hard way. I had probably a difficult start, though, in my career, being raised in the great mountaineering state of Illinois. . .

[Laughter]

But it was in high school that I was reading adventure books: Amundsen, Scott, , The Endurance, and books like that. I came across this tale: This is a story written in 1950, and it details the first ascent of an 8000-meter peak. There are fourteen 8000-meter peaks in the world roughly 26,000 feet and above. In 1950, a French team climbed this peak called Annapurna. They succeeded, and it is a very amazing story. It inspired me to start climbing mountains.

The first thing I had to do, obviously, was to get out of Illinois, and I chose to move to Seattle. My other goal in life was to become a veterinarian, so I studied veterinary medicine in the Seattle area. I started climbing voraciously and learned from people that were very experienced, very conservative and willing to teach me their craft. Eventually, I landed a job guiding on Mount Rainier, 14,400 feet, which I have now climbed 192 times. Most of those times were as a guide. I truly believe that my safety and success in the Himalayas is because of my guiding experience, because as a guide you always have rather inexperienced clients in tow. You are responsible for them. You always have to be evaluating risk and always asking yourself, if this happens, how do I get out of that? So you are always trying to think ahead or not waiting until something were to happen. I truly think this has helped me a lot in the Himalayas.

As I was guiding and climbing higher and higher peaks, I started dreaming big. Obviously, the highest peak you can dream of is Mount Everest at 29,035 feet. I thought that if one day I had the chance to go there, it would be an amazing thing. On the summit there is one-third the amount of oxygen that there is here at sea level. There has been to date many people, almost 2000 people that have stood on the summit of Mount Everest, and this is the kind of clothing that we wear. It is very lightweight. It's very technical. The boots are thermoplastic. There is foam insulation. The fabrics we use are single-layer Goretex, breathable, waterproof, and these products insulate us, but we still have to move to create body heat. We don't have any internal heat source other than our bodies. Basically, these products do not help us climb the mountain, but they make it safer. We climb faster and more efficiently. Most people that climb Everest -- I'd say 95-98 percent of the people that climb Everest -- use supplemental oxygen. Even with supplemental oxygen, it is very difficult to climb this mountain, because the oxygen is mixing with ambient air, and you are only really reducing your relative altitude a couple thousand feet. It is still very difficult, but I decided long ago that if I ever had the chance to go to

Everest or one of the other 8000-meter peaks, I would not use oxygen to climb these mountains. I thought it would be more interesting to challenge myself and to see if maybe I could get to the summit rather than guaranteeing myself getting to the summit. So, that is a rule that I made long ago and something I've lived by.

I had my first chance to go to Mount Everest. There you can see Everest on the left and the peak of Lhotse to the right. This was in 1987. We were climbing the North Face, the face on the left side. With my partner, Eric Simonson, we were part of a large team of about 10 climbers, and it takes 2 _ months of climbing, setting up camp and carrying loads to just get into position to go to the summit. In the end, if you can get one or two people from that team to the summit, then that is teamwork, and that's a success. So, Eric, whom I am looking down on here at 28,000 feet, he and I were here making the final dash to hopefully get to the summit. I was climbing without oxygen, and here is the last 300 vertical feet of the summit ridge to the top of the world. It was kind of late in the day, and the weather was changing. Eric, rather conservative as am I -- we were looking at the top, thinking that we could probably get ourselves to the summit, but we probably wouldn't get ourselves down. For both of us, that seemed to be a huge decision-making factor. I have always felt that climbing has to be a round trip, right?

[Laughter]

But a lot of people lose sight of that. They see this goal that's two hours away and they've spent years of preparing and training and months of climbing and when it gets to that close of a distance, they're willing to throw caution to the wind simply to get to the summit and then, hopefully, they'll get down. And a lot of those people, unfortunately, never make it back down. For me, the risk is too great -- I don't want to die going to the summit of the world. So we walked away -- 300 feet from the top. And it's something I thought about every single day for three more years. Two years later, in 1989, I climbed the second highest peak in the world -- this is Kanchenjunga. We climbed by a very steep and difficult route -- this is the technical climbing that we had at 24,000 feet. Very strong team, rather good conditions, and in the end, we reached the summit and this is the top of Kanchenjunga at 28,200 feet on a very, very pleasant day. And if the weather's good and you have time, you can stay for about an hour on the summit. If the weather's bad, three minutes, take some photos and down you go. We stayed for an hour. And there, looking 80 miles to the west, you can see three more peaks in the distance. And the one closest to the center, the large one, is Everest. And even though I was there standing on Kanchenjunga, I was longing to be back on Everest to finish that last 300 feet.

A year later, I did go back to Everest. And here I am -- you can see me on the ridge in the snow there -- making the final ascent, 300 feet away from the summit once again. Climbing without oxygen at these altitudes, you go very, very slowly. You take a step and you breathe

15 times. You take another step and you breathe 15 times. And then you think about taking another step and you breathe 15 times.

[Laughter]

But after 12 hours of continuous climbing from the high camp at 27,000 feet, I then finally stood on the summit of the world. And to me, this was the most amazing point of my career -- to be on the top of the world. And I've always told people this is the closest you can get to outer space without actually leaving the ground. And this was an amazing moment for me. I then continued -- and this is the view from the summit of Everest there on the horizon 80 miles to the west. To the east is Kanchenjunga, so that reverse view did come true.

The following year, I went to K-2 -- this is the second highest peak in the world -- and by all means, much more difficult to climb than Everest. It's steeper, the weather is worse, and only 200 people to-date have climbed K-2. And I went there with my great friend from Seattle, Scott Fisher. And this is the type of shelter that we used. This is at 26,000 feet -- this is our last camp before we make the final dash to the summit. These shelters and these tents, they weigh about five pounds. And this is the summit day. On K-2, the higher you go the steeper it gets and the more dangerous it gets. And that's where you really, really have to be careful and that's where a lot of accidents occur, because people are so focused on just getting themselves to the top, they're not even aware of the weather, their surroundings, and the conditions. And that's something that you really have to evaluate every step of the way. There I am with my great friend, Scott Fisher, on the summit of K-2. And luckily we climbed it on the first attempt. And once you climb K-2, you never thought of going back.

[Laughter]

I also met that year on K-2, another great friend -- the tall guy in the picture is Rob Hall from New Zealand. We became great friends and did many climbs throughout the world. We climbed Everest together several times and here I am reaching the summit of Lhotse, Everest's neighbor. Lhotse is the fourth highest peak in the world. And what we started to do was to do tandem climbings where we would go and climb Everest over a two-month period, acclimatize our bodies, and then quickly in succession climb another 8,000-meter peak in just three days. And so we could utilize our acclimatization.

Tragically, though, both Scott in the foreground and Rob in the middle died in 1996 on Mt. Everest during the tragic storm of May 10th. I was there with my wife. I was the climbing leader for the Everest IMAX film. My wife, Paula, was our base-camp leader and our expedition leader and director of the film was David Bashir. Very experienced climber, very detail oriented and an amazing leader to have on this climb, which you had a very difficult task in taking a 42-pound camera to the summit. Doing what other climbers were doing -- climbing the mountain and also schlepping this giant microwave-sized piece of metal to the summit as well. And after six weeks of climbing, we were in position to go to the summit. We were going to go on May

9th -- this was a day ahead of everyone. We evaluated the weather conditions. The weather patterns weren't what we were hoping they would be and we decided to go down. Our friends, led by Rob and Scott, made the decision to continue on to the summit on May 10th and then, sadly, the storm occurred and on that day, eight people died -- two of them my great friends. There was nothing we could do. We couldn't climb up to them fast enough; we couldn't get a helicopter to get up to them. And that's the thing about mountaineering. It's one of the places on the planet where rescue is literally impossible unless you send humans to go do the rescuing. There's not machines and there's no other way to get these people.

Part of the reason I think that the tragedy occurred, people were swayed by the group decisions that were made and it was almost like if six people are going, then ten people are going, then twelve people are going. You know, there's comfort -- there's psychological comfort -- in groups with larger numbers. And I think people would say, "Well, they're going, so I'm going to go." And then they kind of just kept pulling each other up higher and higher late in the day as the storm was brewing. We helped with the rescue. We quit filming. We stopped what we were doing. We helped bring some people down and then after that, we managed to pick up the pieces and we went back up the mountain two weeks later. Not in spite of what happened, but I think to show the world that you can climb these mountains and live to talk about it. If you find the right conditions and if you wait with patience for the proper weather, you can climb these mountains and live to talk about it. And this is a scene from the film that David shot from 28,500 feet -- probably the most beautiful scene of the movie. And a short while later, we reach the summit, which is half the trip, and the most important half of the climb is, in my opinion, the descent.

I've gone on to climb more. I'm on a quest or a goal to climb the 14 8,000-meter peaks in the world without supplemental oxygen. And over the last 15 years, I've managed to climb 13 of them. I have one more to go, which is called Annapurna, which is the mountain that got me into all of this, so maybe it's poetic that it happens to be the last mountain on the list. Thank you.

Male speaker: Great, thanks, Ed.

[Applause]

Chris McKay: I just note in passing that the Mars atmosphere has a little less than a percent oxygen, just from [photo dissociation]. Maybe Ed could work it there, too.

[Laughter]

The next speaker is Penny Boston. I've known Penny Boston for a long time. I actually met her in freshman chemistry class. I hated the class, but that wasn't a reflection on Penny. Penny and I have worked together for a long time. When she was a grad student, she started -- she was part of an activity that became known as the Mars Underground. But little did we know that it would be so true for her as her work has taken her, literally, underground. In '92, Penny was the first author on a paper suggesting for the first time that if there was life on Mars, it would be underground and it would have to be chemoautotrophic, getting it's energy from chemistry. What she's been doing then since that paper -- which was a theoretical paper -- is putting it into practice exploring the deep underground on earth. It's a place like what Ed was saying about mountains. It's a place where if something goes wrong, only people can come down and get you -- there's no magic moles or helicopters or rovers that will go down and rescue you. So Penny's no stranger to danger. So Penny? Tell us about it.

Penny Boston: [Unintelligible] I'm no stranger to danger. Well, you know, I've been trying to get to Mars ever since I was a little kid. And my solution to this over the last decade or so is really to go down instead of go out. And that may be as close to going to another planet as I ever get. After we published the paper that Chris just alluded to, we were looking for ways to study the sub-surface. And of course, the most immediate obvious thing was the new information we were getting from drill holes. People were beginning to drill through the DOE project and try to look at the sub-surface -- deep sub-surface microbiology. So we discovered that caves were there and that maybe they would be cheaper to get into. And so after the early part of my career working in extreme environments on the surface, I decided to try caving. And although it was very difficult -- and the first cave I ever caved was [Wachadia] Cave in New Mexico, which is a notoriously difficult cave. And all I thought at the time was am I going to live to get out of this? I just have to live to get out of this cave. Oh! Maybe go away. Here, we'll get that back up.

But after the pain sort of faded, I realized that it was an amazing environment, that I'd never done anything in any place that was so potentially fascinating for the kinds of exotic microbiology that I was interested in as an astrobiologist. And so I realized that I could do two things. One is, I could learn how to cave safely and I could go to these places. And I could then refocus my work to essentially tap into an entire area of biology and mineralogy and the way they overlap on our planet that had not been studied before. This is a new field, really, in terms of what we've been doing on earth. And then it was immediately applicable, of course, to the situation of life beyond the planet. And so most of my research now is focused in one type of cave or another.

So of the number of different kinds of exotic environments that we work in in caves -- and we tend to pick them for their specific chemical properties, so we're looking for caves that have poisonous atmospheres, that are very hot, that are very cold, that are very extreme in some sense so that we can look at the limits to life on this planet and learn from that what may be adaptive strategies of life for other bodies in the solar system and perhaps someday beyond. So really to write a field guide to unknown organisms is part of our mandate.

So I'm studying the caves that we are looking at as I'm going on the work of other cave scientists in the world, there are a number of really clear lessons that we're learning. This beautiful image here -- and you can see down -- there's a little person in a caving helmet there for some sort of scale. These amazing environments show us that caves are really not rare. If you have only ever been in caves as an occasional tourist in a show cave, you may think that caves are a rare phenomena, but really, there are a tremendous number of sub-surface voids on Earth of all different kinds. They aren't just in calcium carbonate-type environments, which are the ones that we often come in contact with, but they really occur in every major rock type. And this is an important lesson for trying to apply our knowledge of Earth caves to other bodies in the solar system. There are many, many ways to make caves. And so one of the areas of active research that we're engaged in is really a set of thought experiments about how you can look at the basic physics and chemistry of environments and try to imagine ways that sub-surface voids on other bodies could be formed. And so we're working that end of the theoretical spectrum of imagining caves on other planets.

The type of cave that we absolutely know exists elsewhere in the solar system are what are known as lava tubes, and these are a natural outgrowth of flood basalt type, quiet, flowing lava eruptions. And these things are essentially rivulets that freeze on the outside. The rock on the outside freezes. It's a very good insulator and then it allows the interior to remain molten and continues to flow through. Eventually when the eruption stops these empty out and you have these beautiful tubes, and so that's a very different class of cave from the kinds of dissolution-dominated caves that we often think of.

Certainly it was known and recognized by Ron Greeley and other colleagues even in the Apollo era that a lot of structures that they were seeing on the moon were lava tubes, or unroofed sinuous reels, which is like a lava tube without its top. As we get ever better imaging of the planet Mars we have seen that there are lava tubes scattered widely over the planet, and these are quite easy to pick out. You can see this image on your upper right of Olympus Mons. It has this little pit crater or little pit collapse feature string-of-beads kind of appearance. This is a direct analogue to the way we find these sorts of things on Earth.

One of the interesting things that's been attributed to the fact that the gravity on Mars is much lower is the fact that the lava tubes scale accordingly in the large directions. So not only does Mars have enormous examples of volcanism but it has big, wanton lava tubes. The biggest lava tube on Earth is about 90 kilometers long in Hawaii. That's the record-holder on Earth. But typically, when you look at these features on Mars they're hundreds of kilometers long. And the diameters are equally great so they're on the average of three to ten times the size of the average diameter of a tube on Earth. So these things are truly enormous.

Not only those places, but when we look at the radar imaging data from the Venus missions you can see that there are tube-like structures associated even with those weird-looking types of volcanic features that you find on Venus. And then even Io, which is such a cooking little moon out there with its tremendous sulfur component, seems to have what is clear evidence of lava tubes. And my dream is that somebody will get a really good image of one that's made out of entirely molten sulfur.

So these are fabulous features but they're also places, and this is one of the areas in which our research has gone. These are places -- at least on the moon and Mars, although I wouldn't recommend astronauts going directly to Io or Venus -- that can actually be exploited as human habitat. We just finished a Phase 1 and Phase 2 study over the last four years for NIAC which, if you're not familiar with it, is the NASA Institute for Advanced Concepts, looking at the far-future conceptual development and looking at ways to discover the likely enabling technologies that we would need to make these actually useable for structures for astronauts and bases on the moon and Mars in the future.

So I'm not going to talk about all the different kinds of caves because that would be a several-hour lecture in and of itself. But one of the points that I think I want to really press home is that cave environments are typically radically different from the surface. These pictures taken in Saudi Arabia by the very well-known caving team of John and Suzy Pinch have shown that even in these very hot blasted sand deserts when you get into these very large bell-shaped caves there are diveable pools. And the air in these caves is near saturated humidity. So it's a complete change from the overlying environment, even in caves that are not sealed. And so it's just the barrier of above and below that provides this radically different environment. And this is a big message for astrobiology, that just what might be dominating on the surface of a planet is not necessarily the key to where you actually have to go to look for the life.

Cave environments obviously have no sunlight, so this means that any organisms living within them have to make their living elsewhere, either by detrital organic material washing in or, in the case of a lot of the organisms we're studying, they're essentially rock eaters. These guys are disaggregating the parent rock using things like the metabolic product, the organic acids that they give off, and then other organisms come along within these little micro communities and they oxidize the metals in the rock. And this is how they get the energy to run their entire ecosystem.

They're very high-humidity environments. In contrast to the surface they're very thermally stable, so even a cave with a big gaping open entrance still remains very, very thermally consistent on the interior. New transfer is usually very, very low with some exceptions. And I'll talk about that in just a minute. They're very rich mineral environments. And then there's no conventional weather, so it very much is a very different planet in the near crustal caves than it is on the surface.

And the results of all these tremendously different conditions that you get in caves -- caves are unique mineral factories. There are vast numbers of unique mineral formations that are found in caves. Huge catalogues of them have been seen and the explanations for the occurrence of these is very much in its infancy. One of the things that we are working on extensively is which of these types of mineral formation processes are actually biogenic, and it turns out that there are a lot of them -- perhaps even most of them in caves have a biogenic component.

So the organisms that are actually contributing to what's going on in caves are not simply passive observers or users of the environment. They are mineralogically interactive. They are changing the caves. They are actually interacting with the bedrock and they are guiding, and in some cases controlling, the kinds of mineral deposits that are left. And this shows just a few beauty shots of some of my favorite ones. A lot of these organisms are novel, and I would venture to say that the bulk of the organisms that we find are actually novel. They're not known to science. And so from one little cave puddle to the next perhaps we have 80% novel organisms that we look at by molecular phylogenetic techniques. So these are truly evolutionarily self-contained environments and many of them are actually physically isolated from the surface and so in that sense they really are little miniature planetary systems within our own crustal environment.

Not only do the caves house this amazing array of organisms that we're just beginning to understand and study, but also they're wonderful preservation environments. So if you are looking for biosignatures, then the sub-surface in caves is the place to look. Not only do the organisms live there, but they very often self-lithify. They're engaged in self-fossilization while they're actually alive. And this picture at the top shows what are known was U-loops from [Lechugia] Cave. And these look very organic. They are entirely rock now, but we have been studying their living counterparts in modern caves and these are clearly the fossilized remains of microbial [mats] that were inhabiting this cave probably on the order of four to six million years ago when this cave was actively forming. We can also expose the fossils in this kind of material by acid etching and the insert that you see in the lower right-hand side is fossil microbial filaments in mats and even preserved [unintelligible] biofilm that you see in these structures.

In a lot of these subterranean worlds we really are the aliens, and this is a very imagination-stretching experience. It's the kind of thing where it would be lovely if we could take a lot of program managers into this kind of environment because really it's the kind of thing where if you are just reading about it it doesn't make as much of an impact as if you were actually doing it.

This particular image comes from Cueva [de Villa Luz], which is one of our most amazing caves that we're studying. It's a sulfuric acid-saturated cave in Tabasco, Mexico. Gases from the nearby volcano, El [Chico], now actually come into this cave and make it an extremely poisonous environment within which to work -- tremendous amounts of hydrogen sulfide, carbon monoxide, carbon dioxide, even aldehydes, and various other noxious things. And so it requires complete protection from that environment.

The message here is that this cave is the most biologically-rich cave of any that we've ever seen, and it's because of these poisonous gases. These poisonous gases are not poisonous to the organisms that are living there; it's home sweet home. And this is the message. We're not looking at extreme environments just to look at extremes where organisms are just barely hanging on. We're looking at them to look for organisms for which that is the comfortable environment because those are representative of what we may find as the average conditions on other bodies.

So we're trying to write the field guide to unknown life, and this is a really tough thing to do. But the place that I've been in my career where this makes the most sense to me is in these kinds of protected and evolutionarily sequestered environments. A lot of the material we look at doesn't even look alive. You can see on the lower right of the screen this white muddy-looking stuff on the walls -- that's living mud. That material is made out of [cells] and filaments that coat itself with calcite mineral. And they're actively producing this material in caves all over the world.

The image of me on the other side shows me looking at these little tiny white dots on the walls. These are organisms that are busy dissolving the salt in a lava tube and making their living there. So even though something may not look alive and sometimes we have to work very hard to show that it's alive, all of these environments contain amazing life forms that are busy also leaving traces of themselves.

One of the other aspects of doing the kind of cave work that we do is also giving us operational experience that is very valuable to future life detection missions, whether they be robotic or, ultimately, crewed teams in the future. And that is that we are operating in extreme environments that are hazardous with an indigenous, sensitive, alien, biology. In this case, the alien biology is on our own planet, but nevertheless, it's very different from our surface environment and we have to take all the precautions that one would imagine in order to avoid contaminating these while at the same time, managing not to kill ourselves off and working in very difficult conditions. And so, it is an analogue for operating with life-detection constraints, including even the aspect of working with various collaborators at MIT and JPL and NASA-Langley on robotics that can get us into some of these kinds of environments. So the caves are out there. I know that as time goes on and we explore the rest of the planets in the solar system, we'll find better and better ways of actually detecting caves besides the lava tubes. We'll find ways to get into them. We'll find ways to drill into them--which will be a lot easier than just sinking a core right down into solid rock--and those will have amazing structures, amazing minerals, and perhaps even amazing life as we explore them. Thanks.

[Applause]

Chris McKay: Great. The next speaker is Nathalie Cabrol, who's at the SETI Institute of Math at [Ames]. Nathalie is a planetary scientist by training and does a lot of the work using the results from robotic missions to Mars and other worlds, but also is directly involved in exploration herself, in particular in the highest lakes in the world in the Andes. That's what she's going to talk about: Exploring the limits of life in those high lakes. Nathalie?

Nathalie Cabrol: Thank you, Chris. I am a planetary geologist, so I am kind of revolving between Earth and Heaven, and part of Heaven is Mars. And as such, I am very privileged and also very proud to be part of Mars Exploration Rover science team, which is proving a lot in terms of exploration, as we were speaking. And as a member of the science team, with my colleagues, we are taking intellectual risks. We have been working for several years to select landing sites, and we thought that these landing sites were actually matching the objective of this Mars exploration rover mission. And so we sent the rover over there and we were very happy to see that indeed, there is a lot of what we were thinking about down there.

But although it's, I would say, an intellectual risk, it's also a risk for the asset and for the time of people that has been put into preparing these missions. There is no human life involved in that part of it, but still, you want to make sure that you are doing your job properly. And to do that, you have to do your homework. And there is no way--although if one was asking me, I would volunteer right away to go to Mars--[unintelligible] these people around like Mr. Lovell and Jack

Schmidt and all these people who made me dream as a little girl and I knew that whatever I was doing with my life, it would involve NASA, planets, and exploration. But still, you have to make sure that the concept you are pushing forward is as close as possible to the reality. And to do that, we had to do a lot of planetary geology here on Earth and to try to find the best analogue we can.

And I am interested in lakes. I am interested in past aqueous environments on Mars and their habitability potential. Whether those are the best place for life, did life ever appear on Mars, these are my drivers as a scientist. And to try to understand that, I am exploring high lakes. Why exploring high lakes? Because the higher you go on Earth, the earlier you go back in time. On Mars, basically, you will be going into a core environment temperature that is really low and you are going into thinner atmosphere and you try to understand what is happening over there. And so we are exploring those high lakes. We have been starting in the Andes. And these are volcanic lakes.

And our goal is astrobiology, but as we are going, of course, our exploration kind of caught up with us and we discovered a brand new avenue of research over there. And this was involving physiology and medicine, and I'll talk a little bit more about that and, of course, education and public outreach.

Well, why going high? As I said, these are the best analogues to Martian lakes and we want to understand the limits of life. And why do we want to do that? Because right now, the Mars exploration rover mission has proven beyond doubt that Mars was a habitable planet for the type of life we know here on Earth. But that does not mean that there was life there; habitability and actual life being two different things. So, going back to these high lakes is for us to make a point to understand: Is life possible in analogous conditions to those on Mars? So we are going up there and we are trying to start with crater lakes in the Andes and we'll try to move on to the Himalayas, because as the lakes in the Andes are slowly receding now because of the climate change, by the same token, on the other side of the planet in the Himalayas, large glaciers are now melting and they are creating new lakes that are probably higher than those of the Andes, and this is, for us, a place to really stop and witness the ecosystems forming: How life gets there and develops, et cetera. So this is really something that's fascinating.

And we started with the Andes and, well, you have to imagine, about two years ago, myself entering the office of my Branch Chief at Ames and saying, "Hi, chief. I think I have this very bright idea. I would like to climb a twenty-thousand foot volcano. By the way, it's not extinct. And there is a lake on top and I want to dive on that lake. Of course, it's almost freezing temperature, but I forgot to tell you something, I am a free diver. I am not using oxygen. Can you help me with [unintelligible]?" He actually did, and this is how we started the Lake [Conchobar] adventure.

And it has been--you know, we were talking this morning about risk and payoff. It has been the most rewarding experience of my entire life so far. We were blessed by the fact that the crew that we took there--nobody was hurt, nobody was really in significant trouble--well, you will wake up lousy at altitude because this is the kind of thing that happens, but nobody got actually sick, I think, from mountain sickness. But, of course, a branching [strain] is okay for that, but we had to work with [Cochu] for six months. And among the people who advised us on this trip was Peter [Hacking], and you know Peter, and Peter was one of the other guys climbing Everest without oxygen. So we took this very seriously.

But in the meantime, as is part of exploration, you open one door and many, many others open as you are walking. And so we started climbing Conchobar and trying to determine if there was life up there and as the title of our project was "Exploring the limits of life in the highest lakes on Earth," I had never imagined that that could be testing our own limits. And not only were we writing the experiment, but we became part of the experiment. And this became fascinating. This is a height chart. It is just to show you how analogous those places are to ancient Mars. The pressure is the same. The temperature is the same. UV radiation--well, according to models, we shouldn't be very far off on this one. It's a very arid environment, yet the [caldera] is right next to it. We're in a volcanic environment with variable thermal input, and, well, if we have questions about life on Mars, when we go to these lakes, we discover that life is thriving over there.

And so to us, that was very, very encouraging. Because also, then, this opens doors and potential for the study and the search for life on Mars.

And going up there normally would help us to understand better from the standpoint of the biology, but it helps us also to prepare for a future mission on Mars, because we have a better idea of the type of instruments, of the type of exploration strategy, what would be able to prepare and [unintelligible] from heads up to management. And this is very important too.

The photograph you're seeing here is from the summit camp, which is actually around 19,500 feet. We are looking down to two evaporation lakes. One is Laguna Verde to the left. One is Laguna Blanca to the right. These two lagunas are lakes which were really perennial lakes 15,000 years ago during the last glacial maximum. And since then, because of climate change, they have been evaporating. And we are using those two lakes, which are at 14,000 feet, as an acclimatization area. And we are studying them.

And once again we stumble into the unexpected. Which is the sense of exploration. And as we were just hoping to spend a little time there, to prepare for the ascent, then we started discovering that, hey, we had more analogy with Mars than we had bargained for. Everyday at the very—I would say clockwise, at 11 o'clock, because this is a thin atmosphere because you have this big gradients of temperature because of the high volcano, you will have this huge dust devils roaming around those lakes, and they will engulf your tents, and your refuge. And you better not be in the middle of it. So that also tells us about human exploration, that there are things you must be aware of.

But what we stumbled into is that. And these are stomatolites. And the field we stumbled into is 150 square kilometers. And these are on the paleo shore of this larger lake I talked about, Laguna Verde, Laguna Blanca; 15,000 years ago this was one lake. And these are fed by hydrothermal springs. And we discovered those stomatolites. And when we assembled those structures, we discovered that they were biogenic, means that we had blue and green algae forming then, and we know that these organisms, microorganisms are the ones that existed on planet earth. And you have to go back to archaea to see this kind of creature.

So we are on the shores of lakes that are very much analogous to what we are seeing on Mars, and all of a sudden we find those primitive terrestrial organisms just colonizing everywhere they can. So that's why I would say the cherry on top of the cake. We are not expecting that. We are hoping to develop this aspect, because obviously this is going to tell us a lot about the potential of these kinds of lakes.

So we studied the structure, but we are keeping in mind that volcano here, because this is [unintelligible], seen from the Bolivian side, from the side we are hiking on. And the scenery here, the lake you are seeing is Laguna Verde, from the ground this time. The white thing you are seeing is salt. This lake is three times saltier than seawater. I learned this the hard way when I tried to dive in it.

[Laughter]

[Unintelligible] pounds of lead would take me to the bottom without any problem. I was floating like a cork pushed by the wind. It was an interesting experience, an interesting dive. So they are stomatolite-like colonies. Because what I didn't mention is that we have all these fossil stomatolites that colonized the paleo shore of this lake. But even better, there are still stomatolites forming today. And this is a very rare occurrence on earth these days. And we are walking on them literally on the floor, and there is better news than that I just received like three weeks ago, some analysis from the lab from this week, and this is a dead ringer for [unintelligible], whatever we think a [unintelligible] is, the chemistry is the same exactly.

Our goal was the top of [unintelligible]. And not only do you want to dive on top of this volcano, but you have to get there. And you have to climb 1,600 meters, which is something like 5,000 feet I would say, in this kind of material. Fortunately, we have the right person to help the team, going up. And this is the oldest member of our team, he's 83 years old, he's a high mountaineering, and he's always second only to the guys. So the youngest guys behind don't want to be left behind, and they run after him. And this is happening every year.

So we have to go through this. We have to make sure that nobody is suffering from hypoxia, from any type of problem. And once you get there, what Peter advised us to do is that although it seems like such a short—it's 1,500 meters, we don't want to do it too fast, because we don't want to be anoxic at the summit. And so what we do is that we stop at night at 18,000 feet, and while this is the only flat place we can find on that volcano. Basically this is a 12 meter by 4 meter kind of flat, and we are jamming our four or five tents over there. What you don't really see maybe from here is that right there you have an 800 meter drop. I didn't mention that to [unintelligible] before we went there. But the slope is about a 40-45 degree slope, and this is very unstable material. But we can stabilize it with [unintelligible], and the only thing we can hope for is that there will not be an earthquake that night.

So once we are there, we spend one night there for acclimatization, and we usually go up, and once we are on top, the scenery is quite something. The lake itself is a receding lake now, is about a football field large. And the paleo shore you can see from here are those that mark the level of the lake in the '50s. That also tells us something. Those lakes are disappearing. It is really time for us to understand what is going on there, because they will be lost forever in a few years. So to the left you see our team pulling out of the crater in 2002; the image, the large image, is from 2003. We actually go in the lake last year.

So when we went there, of course we wanted to dive. We have several objectives when we are doing this. The first one of course is to characterize the habitat and microorganism and ecosystem that is there. And most of this lake like Laguna Blanca or Laguna Verde are a very shallow lakes, which means that also the UV radiation, the microorganisms are going to be affected by that.

The other thing that we are doing is to do physiological research. At Ames we have the astrobionic group, which is developing the sea pods. These are [unintelligible] keeping track of the team. You are monitoring your blood oxygen saturation, you are monitoring your heart beat and apnea during sleep, because this is happening when you are in mountains. But the thing we wanted to do here was a little different.

I am a free diver. I never dive with oxygen tanks, because I find them heavy and cumbersome. At 20,000 feet I had to convince many people that it was a good idea to hold my breath. But basically people in good health at this altitude will be at about 65 percent oxygen saturation in their blood. And their heart is pumping at around 135 beats per minute.

And we wanted to understand what was going on with the oxygen saturation by doing the free diving. Because there are things we cannot do at sea level, because your blood is always saturated in oxygen at sea level. And if something happens to this saturation and heart beat system you will see it at this altitude.

And I also as another motivation -- the very overarching objective somewhere is that somewhere there is an organism, your body is going to produce one way or another more oxygen then we need to understand that. Because we have many people in this world who are dying from lung and heart diseases. And helping those people breathe better, or maybe find a solution that will help them, is something that is really important to us.

And it also, I took this point home because—and this is a little personal story there—I had my father passing away from massive heart failure a few months before the expedition. And witnessing his last days in the condition he was being in, and the difficulty he had to breathe, I said that the only risk I could take would be to have one more person to suffer that thing.

So this is where in my mind there is no question about the risk entailed. If some people wonder why we are exploring, I tell you I know why I'm exploring.

So we did that, and we actually monitored the free dive. And we realized that people can be very well with a heart beat of 39 beats per minute—this is how low my heart went when I was diving there—and getting out at 20,000 feet of that kind of water which is at 40 degrees with a blood oxygen saturation at 93 percent. Something is producing oxygen in our body. Something remembers that we are aquatic mammals. We need to understand what it is. Nature gave me two good lungs. Actually, Stanford is looking for the third one.

[Laughter]

And a good heart, and I want to take advantage of that to help make headway, to find solutions for one of the most horrendous killers in our society.

So this is one of the aspects of why it is worth taking risks. On the other hand, on the more -- I would say, exploration -- NASA-related objective -- those monitors, these physiological monitors -- they tell you about everything that you want to know about a crew's status of health. It was really important for us to show that this was working, and we actually did some live transmission of our vitals directly to Ames and Stanford while we were there. That was the first time this was done. That was one of the co-aspects. The other aspect, going back to astrobiology and microorganism, is that we are actually now in a position to know a lot better those microenvironments. This is one photo from the [unintelligible] Lake.

In the past two years, we have also been involved in pinpointing some interesting effects of the UV radiation. To the very left of your screen, you are seeing a normal diatom. The three other images to the right: On the top image, you can see all the categories of mutation or malformation that those diatoms are experiencing due to UV radiation. The same thing appears in the bottom one. We want to understand this because it tells us something. At first I talked about mutation. Yes, there are apparently mutations that we need to understand better if it is a mutation toward extinction or if it is a mutation toward evolution. It is really important in a world where you have high UV impact such as Mars would have been in the past. The other aspect of it is that we are living in a world where UV impact is becoming more and more of an issue. We have trouble with the ozone layer, and if these little creatures over there are developing sunscreen and UV [unintelligible] strategy, we need to learn about it because that will help the general public.

And, of course, as you are exploring, you find fun stuff. I just put in these slides to show that sometimes we have interesting encounters. The very first image on the top left is one of a diatom that was thought to be extinct a long time ago. Well, it's thriving in Laguna Verde, thank you. It is having lots of success. It is still there. It was thought to be extinct. Another case we found was a diatom that was known to exist only in the Baltic Sea. Don't ask me how it ended up here, but it is there and thriving. Maybe the conditions of salinity and cold are very close to the Baltic Sea. So, on and on, we are learning a lot.

These are a few images of the samples we brought back last year from [unintelligible]. These were the first creatures on earth, and they are still there. They are evolving, but they are evolving [unintelligible]. They are telling us about our past. If we are able to decipher what they are telling us, we will know better about our origins and maybe possible origins from life on other planets because those lakes are very similar to that of Mars.

To go back to what many of the previous speakers talked about, managing risk and people, there is obviously a [unintelligible] and physical responsibility. I have put a short list of the risks we are facing. You have catastrophic risk, of course. There is nothing we can do about the volcano exploding on us if we are there when this happens. Everything else we can manage.

I would say that the state of mind I would go with when I leave the US and go to Bolivia would be to actually say, Well, as much as I can prevent it, nobody will get hurt on my watch. I am always working on this, and I have to manage a very diverse group of people. This group of people ranges from young people, students, to people who are senior scientists to people who speak different languages. Last year in my team I had Hungarians. I had Chileans and Bolivians. I am French. I had American people and Spaniards. That makes for good jokes when we are trying to translate one thing to another. We have to make sure that the safety things will get through all the time. My personal standpoint here is that definitely risk is inherent to exploration, and it is necessary to discovery. And I will go a step farther. I say this is also the essence of survival. If we want to do it, we need to explore. We need to explore new ground.

I guess we have to share an ultimate responsibility as Dale and Penny were mentioning. You have a team with you. You are responsible for them, and you have to have answers. The main thing is that you have to be accountable and responsible for all that. It is hard to think that exploration can be done without taking risk. It is hard for me to think that ultimately exploration can be done without losing people one way or another. Even if this happens, we have to make sure that we have done everything possible to mitigate the risk and to prevent it from happening as much as possible.

Chris McKay: Thank you.

[Applause]

Okay. Let's move to the next speaker. I am going to warn the two speakers here that they are closer to me, so they take a risk is they run over . . .

[Laughter]

Of getting clobbered. Speaking of risk, I think what Bill Stone does is the riskiest. You've heard about exploration, and it sounds pretty crazy. This is going to be really crazy. Sort of like Ed, I remember reading an article about his work. Unlike Ed, I didn't think, I wanna go do that. I thought, This is crazy. I don't wanna be doing that. What he does is explore underwater environments -- underwater cave environments -- distant traverses underwater in caves. He has been doing it mostly by developing new technologies and using humans as the exploration vehicle. He is now the PI of a NASA ASTEP project to develop a vehicle called DEPTHX, which will explore the anaerobic zone of the underwater environment in Zacatón, Mexico that has a direct relevance to Mars and Europa exploration. He involves both the robotic and human exploration side, and he really does crazy stuff. Bill, with that introduction . . .

Bill Stone: I'd say that's almost a set-up.

[Laughter]

You know, I thought a little bit about the differences and some of the things we do here, and Ed, of course, is one of the world's preeminent mountaineers. You have to be careful when somebody labels you like that because, given the probabilities involved, it's a bad title to hang on somebody because it may not last.

[Laughter]

And, you know, when people think about mountaineering, there is always this justification for why you do it. Of course, the classic one came out of Mallory back in 1927, I believe it was. He simply answered shortly to the press, Because it's there. About 10 years ago, I was given the ultimate set-up by somebody from one of the magazine that was talking about one of our projects. He said, Why do you do it? I said, Because it's not there.

[Laughter]

You'll have to think about it for a while. In any event, I've come from a rather unusual background in which I came up through engineering, wanting to be an astronaut. I watched a couple of these guys who talked here this morning do it. They were my heroes, and that was directly responsible for going out and getting a Ph.D. in Engineering and moving on. In the process of trying to get into the astronaut corps at various times, I also had the privilege of being involved on a vast number of expeditionary projects dealing with things that go down into the earth as opposed to things that go up. I added it up a little while ago. Over the last 26 years, I've spent 7 _ years in the field in on expeditions of which 358 days were below 4000 feet underground. So, I'm either a troglodyte or somebody who's looking for planetary exploration and hasn't been able to get off this pile of rock yet.

[Laughter]

So what I am going to do here rapidly is take you to three of the most remote places that humans have ever reached inside this planet. This is serious business, okay? It is more serious, I would believe, than high altitude mountaineering, although depending upon who you ask, they will give you varying weighing-ins on that answer. We don't take it as something you do for excitement. The classic answer, and this came from Stephenson, if anybody did their research on Arctic exploration. Asked about this one time, he said, Well, you're an adventurer, aren't you? He said, Son, adventure is what happens when exploration goes wrong.

[Laughter]

And, I have had that little motto emblazoned upon my heart in letters of gold ever since. You do not get Brownie points for having your name on a tombstone. You have to come back. Like somebody said, it's a round trip. With that in mind, I have actually taken a lot of cues from how NASA trains its astronauts. In this world where we are about to take you, this is a gloves-off world. The exploration front here is now getting to the stage where it is so remote and so difficult to reach that no matter what technology we have at our disposal and no matter how olympically-trained the people are who are involved with it, we still get stomped. Every time you go for four or five months in the field, if you're lucky, you're a kilometer or two deeper into the planet. I am going to give you an idea here just what this world is like. Hopefully this thing will fly.

Okay. In order to save time here, [chuckle] I'm going to compress -- Ed would love this. We are going to give you a combined show here of what would be the equivalent of summiting Everest and K2, but it's all going to be in one continuous slide show, all proceeding down. Rising out of the southeastern area of southern Mexico is the lava plateau. It jumps straight up about 2100 meters. The top of it is cratered with gigantic sinkholes. The water that rains on this area for 500 square kilometers all goes internally and in the process of doing that, it creates some pretty substantially-sized places.

About 50 miles away to the south and over a kilometer higher in elevation, which puts it up around 10,500-11,000 feet is Cueva Cheve. This was only discovered in 1988. This gives you the idea of how new what is going on here is. This place was not even known for the modern world until 1988 -- that was just 16 years ago. The endeavors we're talking about require a lot of technology, starting off with the fact that you're going down. You don't just walk down that depth. If you look at that lower picture you see over there, those white streaks that you see there are two and a half miles of mountaineering rope that are used to rig over 107 drops going down into this cave. Okay.

Typical vertical drops on some of these things can reach distances of 160 meters straight down. That would be about a time and a half the height of the vehicle assembly building, for those who are here from KSC. A lot of times, they're a little bit shorter, but they always almost have water accompanying the drops. The deeper you go the more water you collect. The tributaries each add a little bit in until finally you're dealing with quite a bit. You're rigging lines on the walls to keep out of that, usually. This is a flood on the right -- somebody was talking about environmental factors -- you need to try to think about that when you go into these places. This is life on rope. You're usually carrying around a 25 kilogram pack, which has the supplies that you're bringing. This is very much an inverse problem to the siege tactics that you see used on high altitude mountains where you're building camp one, camp two, camp three and you start off with a pyramid of 50 people -- sometimes we've had as many as 150, but 50 is a typical number for a trip for four to five months -- works out to be a good number to work with, you have some depth for emergencies.

And the further down you go you're definitely doing this until finally you're into rivers by the time you get to about the 800-meter level. This would be a little over a half a mile deep in English units. I know nobody around here works in English units except when you're designing planetary craft going to Mars.

[Laughter]

One of the things that we've had to deal with is the fact that we are exceeding the range of human capacity. Typically, if you go on a marathon trip, you can stay up for 24, 28, maybe 30 hours, and after that if you come back to base camp from the surface, you're out of commission for two-three days, while you're recovering. So you can't do that underground. If you want to move efficiently, your people have to be roughly 16 hours from anywhere that they have to go. And so we begin to establish a series of camps. I want to dispel the notion that a lot of people have that these places are claustrophobic and really have to be concerned about that. A lot of these places are so big you can't even see the ceilings or the walls. It really is like being on the dark side of the Moon. These are team endeavors.

Again, when I think of an expedition -- and this is a sticking point with me and it may be with others -- but there are a couple of holy words in the vocabulary of true explorers. And one of those is the term “expedition.” To me, this is endeavor of 20 or more people being out in the field for four-plus months. That's a serious distinction. Anything short of that is what I would refer to as a recon mission. And so this kind of stuff that you're seeing here, you're on site for four-five months and people are working daily. In between camps, you may not get to the next camp when you're the first crew that's moving in. These are logistical issues where you might be on the lead rigging crew -- like this guy here in the red bag on the right -- and you don't make it to the next camp because you ran out of rope. Well the reinforcement crew comes in the next day with another kilometer of rope and off you go. And then they retreat to the next camp behind them. And so it goes on down until you are now roughly four days traveling distance from the nearest entrance. So when you get to a place like this, you begin to think about the fact that you're pretty remote and there really isn't going to be any rescue except from the people who are with you, particularly if it's something that is of urgent time to respond. If you can get a person back to a camp and stabilize a broken leg or something like that, you can always send out for assistance.

One of these places -- the most remote place that we've been so far is in the bottom of this place called Cueva Cheve. When you get down to a distance of approximately eight-and-a-half kilometers inside and at a depth of 1,360 meters down, you're moving through water like this and you keep thinking that, well, this is just going to keep going down like this. And the problem is that these places are always quirky in terms of geology. All it takes is a slight counterfold in the limestone and that river that was boiling in the last photo is now static, placid, and going down. They used to refer to these places as terminal sumps or terminal siphons. In fact, it's the name of a rock band I'm in, so you'll hear us touring someday. So you get down to a place like this and here you are, you're roughly 4,500 feet vertically down and about seven miles in. Everything down here is paid for preciously by the people who transported this down. You're living on ropes for days to get this here, so you have to be very careful about what you bring. However, somebody brought this up -- I think it was Ed -- you have this enormous pressure on you. And I'm sure that everybody who's flown on a rocket knows this same feeling. Here's 50 or 100 people who have given of their time, of their lives, of their sweat for four months -- that's not counting, by the way in the case of many of these, we have spent two to four months rehearsing with those teams before we got here, especially the groups that are doing what you see in this photo right here. When you get to these places where the tunnels are full of water, now you're in to another level of issue where you have to be aware of the fact that, number one, you're going to be using portable life equipment -- what astronauts refer to as [PLIS] units for EVA. And that's the way I think of this. I think of this as EVA. And when you do that, you have to be thinking a couple of things. Number one is that anything can go wrong at any time and so the best way to deal with this is to believe that this place is actively out to get you. When you think that way, you start making checklists ahead of time. In fact, we have them all laminated on waterproof paper. Not only before you go in, but after you come back out. It's the equivalent of pre-flight and post-flight checklists.

But there's more to this. I'm going to say one thing here and then I'll come back to another side of it. We've been talking about issues for reducing risk, one of them being making things bombproof. That's a bit tough when you look at the places that you have to go through to get these items or the equipment that these people have down here.

And the other one is redundancy. But before I get to that, there's this whole issue of the pressure loading that is on you. You have to be ready at any second on one of these things that if you get 50 feet inside this underwater tunnel and you don't like how you feel, you'll abort. That's a cardinal rule. And somebody was asking me this -- might have been last night -- how many people do I know on expeditions that have died? And I really never think much about it until I started adding it up. And over the last 18 years, I've lost 16 good friends. People that I just -- just like Ed knew -- were people that I've climbed with, worked with on expeditions, people who were very qualified. The reason they're not here right now is because they went a little too far -- they didn't abort when they should have, they didn't stop and say, "Wait a minute. There's a stack of things that are going wrong here."

Nothing ever happens in one blow. Jim Lovell pointed that out this morning. But a string of little events -- you start going down there and you get tired. You get tired and you say, "Ah, I don't need to have this extra little piece of safety line here." And, "Oh, geez, I don't need to check the various equipment I have for descending a rope line." Pretty soon, one, two, three -- something adds up and you don't have that safety on there and when you sit down, one of those karabiners is unlocked and it comes unclipped and there you are with 50 pounds hanging below you and you're hanging on a rope by one hand. You know, that kind of stuff happens. So you have to get religious in your discipline about how you deal with the technology. This is high technology exploration that's going on down here. Every bit as much -- and you'll see when we get away from this series of slides here and into the next -- every bit and perhaps more serious than a typical EVA mission outside the shuttle.

This isn't SCUBA you're looking at here, this is all fully closed-cycle equipment. There is no air in this system. That's all helium oxygen running at about 6,000-psi in carbon-carbon tanks underneath that. Range on this particular rig right here was about eight hours at the depth. We did that because of the fact that we didn't know how far we were going to have to explore under water. Sometimes when you get to these locations, there is no dry land and so you're living in hammocks strung from rock holes above the water and hoping that you're high enough that in case there's a flood you're not going to get pushed away. That's the world you live in when you're down there.

In the bottom of [System Alotma], you're doing 600 meters -- that's roughly a half a mile -- of diving, starting at the 4,500-foot level. When you get on to the other side over there, we established a camp -- this is camp six -- we were over there for a week and explored another three-and-a-half kilometers beyond there. These things are frontier right now. This particular waterfall you're looking at has not seen another expedition in ten years. Nobody has been able to organize the logistics to go back and go further. This is not a done situation, it's beckoning, it's wide open, and yet we can't get the tactical logistics together or the team because they all have to be not only vertical trained, they have to be comfortable with where they are in a remote environment and they have to be able to dive at the same time as well as climb. You start putting all these things together, all these various task loadings, and pretty soon the filters get pretty serious.

This is the kind of thing that you're going to have to think about. Who are you going to put on the moon? Who are you going to put on the moon? What kind of expeditionary qualified people are you going to put on the moon? You know, somebody was talking about -- are you going to live together for a year up there? That's -- I mean, the psychological aspects are one thing, but the multi-disciplinary training is going to be phenomenal. If you get away from this logistical problem that we have of getting stuff down to 5,000 feet underground, and you can bring things in on tractor trailers, the whole ballgame changes. The place I'm going to show you here is, in fact, one of the great natural wonders of the world and you can go see it. It's just south of Tallahassee, Florida. A place called Wakulla Springs. Up until 1987, this place was basically unexplored. You could look at the entrance from glass-bottomed boats, but nobody had really been in much more than 100 feet or so on SCUBA. And we had an opportunity to go there with National Geographic in '87, but it was in '99 that things really got high tech.

I'll just give you an idea here about where need drives equipment development and taste. Every piece of equipment you're going to see in the next few slides did not exist prior to 1999. We built all this on a two-year schedule once we got the go-ahead from National Geographic and corporate patrons.

What you're looking at here is a dual closed-cycle system. Six onboard computers running this thing. Twin head-up displays. 18 hours range, authority to cross-route all the [unintelligible]. There is no EVA in use by NASA that would meet this standard, and I'll tell you why. When you get down there, we're going to be doing missions here of distances of about 4 and a half kilometers from the entrance at 100 meters underwater depth. There are divers in this crowd here, and I'm going to show you some specifics in a minute, but I think you'll understand.

When you're out there, you are 2 and a half hours one-way travel time from the nearest egress point. If you're on a shuttle mission or a station mission right now, and you have a problem with your suit, whether it's an [orlon] or a [IOP Dober] suit, you got roughly 10 to 15 minutes, maybe 30 minutes in open circuit mode, to get back to the hatch. Here you don't have that luxury. You are 2 and a half hours out, and you've got to figure out how you can do it.

Everybody here is in a situation where no matter where they are on that trajectory, if they have an abort scenario. The front vehicle that you see here, this kind of shiny gray tubular cylinders, those are 20 kilometer range life support systems. The guy in the upper left there is actually pulling another one.

The maximum mission duration by pre-agreement among the teams is ten kilometers penetration. And you had a factor of four to one to get yourself back. Everybody who was doing these would rehearse those missions in this basin right here for upwards of 12 hours, and have people come in and tell them for example that all of their vehicles were dead, they had to transfer and get towed out by one of their partners. And then you'd tell them for example that half of their life support system was gone, and they'd have to continue out on that. So you're continuously rehearsing all the various abort scenarios.

A typical mission. This is not as much fun as the first joke about why we do this kind of stuff. This is all about collection of information about what the frontier is. If you're an explorer, you should be out there trying to collect that data, just like Stephenson said, and get back safely with it.

That gadget that you see in front of the lower person on the right there is a one-of-a-kind device that we built for this project. It's got a very high-grade initial guidance unit in it, phased array sonar, and about eight computers. And it's imaging the wall as you drive through to build a three-dimensional map of the [unintelligible]. The person in back is the safety diver. Their job is to make sure that when this person is driving this monstrosity up here, that if they do something wrong, they're going to come up and help them out.

Typically, we would have a support crew follow people in to a depth of about 80 meters. This is perhaps 150 meters into the cave. You can see the difference right away here in what's going on. The guys in the bottom, actually guys and women, are not putting out any bubbles at all. They're running on helium-oxygen, and they'll have 18 hours supply down there. The people on top have got the biggest sport diving cylinders in the business, and they're dumping out about a thousand dollars worth of helium-oxygen on that support mission just because of the fact that they're wasting it away.

And then off you go. For approximately the next 5 and a half hours, with a typical run down here to 100 meters depth, and then you're back. Now you can't come straight out, as somebody like Mike Earnhardt or anybody will tell you who has done EDA. You have a decompression issue, a very serious one. In fact when you're five hours down at 100 meters, you're almost saturated. At 60 meters down we had a string of closed circuit cameras following people out. They had flashcards so they could tell if everything was okay, or they needed supplies from down there. And that thing you see hanging in the distance out there is a pressure transfer capsule. When they reached this stage right here, like something out of a James Bond movie, six support divers would drop out of the sky and come down and take away their closed cycle unit, give them a regulator, and let them switch up into that capsule. They would then be transferred up to the top and into what we call a mini-saturation system, where they would spend the next 12 hours. Total mission duration, about 22 to 24 hours. We did this everyday for three days, took a day off for maintenance, and then did it again for three months while we were down there. No issues with safety on that entire project with any of the mission crews.

Here's a typical duration. Data was logged not only in the light support equipment as well as the mapper there, you can see we're running out to just about a five-hour bottom time out there, and then you're back up. It's the stuff to the right of the bottom over there that's rather interesting. That's where you're spending another three to four hours before you can get into any kind of a safe haven. So your down time is roughly nine hours before you have a chance to get out.

At that point, the crews that have recovered the systems hook up a laptop. They download the tissue tensions and recompute the chamber decompression to get you out. This is what you look like with the service crews. We had people rotating on 6-hour bases. And this is what it was all about.

Ten million data points here to build the world's first three-dimensional cave map. We didn't even bother to measure, like you normally would, to do something like this. The colors themselves are colors assigned to individual mapping mission, and it gives you an idea of how this all overlays.

So in our case it's not only a desire to be out on the frontier, but it's also bringing the data back home. That's it.

[Applause]

Chris McKay: That's a long swim underground. You notice we started underground, up, down, up down, up, down. We're down, so you can guess what David Roberts does. He's a writer. But he also climbs mountains. So he's at the end to give us both the perspective of the mountain climber, and also the perspective of an English teacher—he used to be an English teacher and a writer. It also turns out by coincidence he's the son of Walter O. Roberts, for those of you who are familiar with [NCAR] on Walter O'Roberts mesa in Colorado. Actually, I knew his father. So it's a pleasure to introduce you, David, and look forward to what you're going to say.

David Roberts: Thanks, Chris. I've promised I really will be brief, especially since I don't have any audio-visual aids. And you've been really patient, so thank you for your attention.

I've been free-lance writing for 25 years, mostly about adventure, exploration, spinoffs to archeology and history. But before that I was a serious climber for about 20 years, from 17 to 37. I didn't climb high altitude peaks like Ed, but specialized in technically difficult peaks in Alaska. And I still climb, although pretty pitifully and mellowly.

But for me the most critical question of my life had to do with the fact that by the age of 22 I had been a firsthand witness to three fatal accidents to partners. Starting with my first partner in high school, Dave Lee, who only four months after we started climbing was killed on the first Flatiron above Boulder when, not on a very hard route, but when we got a rope snagged and had to unrope, and then he climbed down solo to retrieve it. He slipped and fell 700 feet with me watching.

And three years later I was the first person on the scene when two guys fell out of Pinnacle Gully in Mt. Washington, one of whom, Craig Merrihew, was actually in training to be an astronaut. And tried to resuscitate them to no avail, and then to have to haul their bodies down to Pinkham Notch.

And then just three months after that, on still my hardest Alaskan expedition to Mt. Huntington, after all four of us had reached the summit, on the descent Ed Burns, the youngest of the four of us, a 20 year old, sophomore in college, inexplicably fell, had a rappel come loose. And we were descending in the middle of the night, we could just barely see in the Alaska twilight. And without my knowing even today what happened, the rappel fell, and he simply fell away from me 4,000 feet, and we never could even look for his body.

Now the question to me now is, why did I keep climbing after these terrible experiences? At the time I didn't even really examine it. I mean I came close to quitting, but I didn't really examine why I kept climbing. I think if somebody had asked me I would have said, well, wouldn't their deaths be even more pointless if I quit climbing.

So when I tailed off climbing and got interested in writing about other climbers including Ed, of whom I did a profile some years ago, I got much more interested in this whole question of risk, motivation, and the risk-reward payoff. And in 1980 I wrote an essay called Moments of Doubt in which I basically tried to, it was an apologia for doing something as crazy and risky and useless as climbing.

My favorite climbing autobiography is Lionel Terez' Conquistodors of the Useless, because it is an awkward but telling phrase. And just this year I've finished a memoir about my climbing in which I actually come to the opposite conclusion, that maybe it wasn't worth the risk. And what changed my thinking about this was that, okay, I had always thought about is it worth the risk in terms of the question, basically sort of a solipsistic, very selfish question, does the reward I get for making a first ascent make up for the risk -- overbalance the risk and the tragedy of someone dying? And it took me 35 years to realize that that was just a completely self-centered and therefore sort of stupid question.

And one of the things I did a few years ago was to go back and recontact Dave's brother and sister, the only surviving members of his family. Forty years after the accident. I had never communicated with them. And I found that his sister in particular was still in a rage with me over that accident, and that she lived with it every day of her life. We spent the most intense seven hours straight in Seattle on a park bench talking about it, and trying to untangle her feelings about it. And

I finally realized that the question of, is it worth the risk, is not one you can really just apply to yourself. It really does involve, as someone pointed out, family, the larger society, and humankind, ultimately.

I guess if I still had to come up with a rationale for climbing mountains, it would not be anything to do with the thrill of it versus the penalties, but rather whether the very endeavor has something very inspirational about it that lasts. And I think by analogy with Scott, and Shackleton and Amundsen in the Antarctic, they justified their expeditions in the name of science. Just as I think NASA is continually doing. And Scott, when he died, had thirty pounds of rocks on his flesh, geological samples. He tossed away everything extraneous but he somehow thought the thirty pounds of rocks were worth bringing back, and [Geri Gerard's] worst journey in the world was to gather penguin eggs in the middle of winter from Cape Kroghr , and under the misapprehension of the now exploded theory that ontology recapitulates phylogeny. Penguins being the most primitive birds in the world, their embryos would tell us all about early human evolution. It's complete bunk. But he performed the worst journey in the world to gather three penguin eggs, but we don't remember Scott, Shackleton, Amundsen for their science, we remember for their example of daring adventure and exploration and going where no one else had ever been. To me that was the first, and is still the most exciting part of exploration, is to go where no one else had ever been. The only rationale for it is if it inspires other people. Ed Viesturs clearly inspires other people. I have been at talks he has given where he has been treated -- the groupies have just gathered all around him. They want more than autographs.

[Laughter]

And, is he a rock star celebrity? No, but there clearly is something that touches the human spirit and as corny as Bush's line says in whoever wrote it for him, the speech writer, the desire written in the human heart really does have to do with something you do at risk and exploration.

One last note, a curiosity from the Renaissance. We're taught on and off about the Renaissance, but someone calculated that on a typical Renaissance fledge to the New World, sailors stood a one in three chance of not surviving, or dying. And that makes Everest look like a piece of cake. It makes Bill Stone's stuff even look safer. And the collectors of the narrative of the voyages like [Kathiet] and [Perches], write often about the adventurers, but the adventurers, in Kathiet's vernacular, or vocabulary, and as was current in England, the adventureres were not the sailors, they were the guys that put up the money. The real adventure was taken by the financiers who backed the expedition. The sailors were just expendable, work hands. All of this needs to be put in a historical, and a multi-cultural perspective. Thank you.

[Background noise]

Chris McKay: Okay, what I'd like to do now is to go to open discussion. Keep in mind what you heard, and keep in mind the questions that would be relevant to NASA. In terms of sending humans to explore. Points that David made – is it pointless to send humans, especially now with technology advancing and people argue, we could send machines. And it ties to these questions that David raised. And what I would like to do is have some audience participation and discussion. Now, you can ask questions of anyone you want, or you can make a short statement. I'll be rude if necessary. What I would like you to do is wait for the microphones and say who you are, give your name and a very short affiliation, just "University of the Midwest," or something like that, and make your question. Okay, Darlene. Stand up, too -- and remember, everything you say is being broadcast live. There are seven words you shouldn't say.

[Laughter]

Darlene Winn: Darlene Winn, NASA Ames Research Center, and my question is for Bill Stone. I wanted to find out what some of the advantages were that you presented, to say it would be more advantageous to send humans into the aquifer and do the mapping that you outline, versus sending in submersibles?

Bill Stone: That's a fantastic set-up. There might be one or two others in this audience, but I think I've found myself in a unique position in having spent about a decade of my life designing spacecraft and another decade designing robots, and now robotic spacecraft. On the other side what people I work with refer to as CFT, or Copious Free Time, we do some work underground. It goes like this, and I'll out it to you as succinctly as I can. There are places where robots are entirely logical to be used first, and I put those in two positions. For one, places that are lethal to humans, and places which are currently too remote to get to without primitive propulsion technology systems. So you put your things in those boxes and figure out where they ought to go.

Everything else, in my opinion, is best done with people. Now, at some point you do have to draw the line in the sand to say this is too risky. As I say when I was looking over this list of departed friends, no different from Jim Lovell citing off a list of test pilots he has known, these are dangerous environments. The reason we are still here is because we knew where to draw the line in the sand. Even if we do that, there is still unquantifiable risk, so the game is to say, allright, you want to be out there in person. Probably everybody in this room wants to be out there in person. Do I want to be here? I'd rather be at Shackleton Crater on the moon right now for a couple of years with a dozen good, qualified people. I'd be happier there than I am here, or at work. That's why I live. That's where people like Ed Viesturs live. If you don't understand that, you need to go on an expedition somewhere remote. Maybe you'll like it, maybe you won't, but the people I work with, you tell right off: the ones that are concerned about where they are, and you see it when you get to someplace, to Camp Three or

Camp Four. In fact, people that I've worked with for years on this have a name for it. They stole it from Jacques Cousteau, it's called rapture of the deep, and you can tell because their eyes are getting wider, and they're sitting there at those camps going "I need to be concerned about getting out of here," rather than focusing on the job at hand, which is pushing the exploration frontier. The people that you find have a bigger smile on their face the deeper you go, those are the people you want, those are the ones you want out there with you at the frontier. Now, to go back to your question directly here, why do this person? Because it is the most stimulating thing that you will ever experience in your life. And I have the privilege of being where no one has been before. If I had to capture a twenty-second image on film that depicted that event and what its importance is personally to anybody who does it, it would be the film that this gentleman up here made with Ron Howard, where they show the image of flying by the moon, and thinking, I could be down there, lifting that [unintelligible] up and looking at it in my hand. That's what drives us on. If you look at what we do in our normal lives, come on. It's worthless.

Chris McKay: Speak for yourself, Bill. We have another question, but I'd like -- Bill just made a very good case for human exploration. I think we want to hear a counter-case, so somebody in the audience -- I don't think I can get any of the panelists to do it -- think of a good case for why the space program should just be robotic, why we shouldn't risk human life. If there's no one in the audience who can state that case, we don't have a well-selected audience. Somebody come up with the counter-point, the argument (so we can pillory them), why robots are sufficient. With that enticement we'll go to the question here, in the red shirt, please.

Steve Cook: Steve Cook, NASA Marshall. I won't take that question, but I will say, first off, I think there's a goldmine of analogies here that are applicable to exploration that we need to capitalize upon as a country to sell and sustain a vision that I don't think we're doing as well as we could today. With all of the experiences you've been having, a lot of these are firsts with me and I've been with NASA for several years. Question now with risk, with respect to Ed Viesturs and to Bill Stone. Ed, you talked about -- you made the decision to hold back. You had the camera crew, this would have been a perfect time to go, your friends did not. I'd like you to talk a little bit about the criteria you used versus what you think or know that they used. Why did they go forward versus why did you stay?

Ed Viesturs: We, when we go to Everest, we spend six or eight weeks preparing for that final day. That's carrying loads, building camps, acclimatizing. And then the idea is that sometime in May, historically, we know that there's going to be a window of favorable weather that would allow us to do that final 3,000-foot climb. So the whole preparation leads to that. Once you're then ready, then you have to take into account everything that you see around you. The weather patterns -- now we can get good weather forecasting. In those days, it was just kind of starting to work, but we would have to base our judgment and what we were thinking about doing on what we were seeing, what we were feeling, our gut instinct has a big role in how I make my decision --

you know, what am I seeing and how has that played a role in what I've done in the past. And we made a group decision -- David Bashir who'd climbed Everest twice, I'd climbed it four times by then, Robert [Shower] -- as a group, we all felt that the weather patterns that we were seeing were not historically what we were waiting to go to the summit with. So we made the call based on that and also just the fact that it didn't feel right. And I think Bill mentioned that I think the reason a lot of us are alive today is because we know when those flags are flying -- those red flags are popping up -- that we have to listen to our instincts and whether we discover later, well, we made the wrong decision -- the weather was good -- well, big deal. We erred on the side of safety and being conservative.

Our friends, they had this date in their mind and that was May 10th. And a lot of times climbers do that. Come hell or high water, they will just go for the summit on that particular date -- because it's auspicious or whatever. And I've always said, ultimately the mountain decides when you can go up and you have to listen to what the mountain is telling you. There are signals and you can't blindly, stubbornly go up because we all know that Mother Nature is much stronger than we are. They did start on a good day -- it was perfect. And had they turned around in enough time, they would have escaped the storm, which came late in the day, which is something that we saw developing every single day the past two weeks previously. But, again, they got so close to the top, they pushed further and further and further away. That umbilical cord of safety got stretched and finally broke. And I can't second-guess the decisions that they made. I wasn't up there. I can evaluate what they did. I can say that I wouldn't have made decisions the way they made them, but again as Bill said, there wasn't one decision that was wrong, there wasn't one person that made -- it was a multitude of little problems and then the straw that broke the camel's back was the storm and then people died.

Chris McKay: Ed, I want to -- I'd like to ask you a question. Do you have a short answer -- a personal short answer to the question of why you climb mountains?

Ed Viesturs: For me it's the -- I'm a stubborn person, I like challenging projects and for me climbing is the most difficult physical and mental thing I can think of doing -- especially without oxygen. And I know I have to train, prepare, think about what I'm doing to be successful at it. And there's a huge struggle to get to those altitudes without oxygen. And so many things can go wrong and when you succeed and when you finally are standing on the summit of Everest, it's an amazing feeling. And it's something I can't find anywhere else and so I've become addicted to it.

Chris McKay: Would you classify what you do as exploration?

Ed Viesturs: I explore myself. And I think that's -- the interesting part, I think also, about climbing is when you're that high, you know, you can be in the middle of the desert, you can be down in the ocean, if you get in trouble, somebody can come and get you. Up there, you're on your own. If you make a mistake, you have to get yourself out of it. And it's a very rare feeling that we don't get. As normal, sea-level, land-lubbing people, we don't get that feeling of isolation where we think about every single step and every single move that we make, there can be consequences because of those. And that's an interesting thing that I feel up there.

Chris McKay: Thanks. We have a question here and, please, the mike over here, Victoria, for the next question.

Dennis Windau: Hi. Dennis Windau, Skycorp, Incorporated. And this is kind of for Neil, Ed, and you, Chris. I see a commonality between what you do on the mountain, what you do underground, and what you do in the Arctic. And the commonality is a staged approach, abort modes -- you don't do everything in one big, fell swoop. And it seems that in the space arena that we try to do that whether it's a manned system or whether it's un-manned. But especially in the manned, because there's a religious argument -- I call it -- going on now at NASA: Do we build a heavy lift launch vehicle or do we use the assets that we have to go back to the moon and on to Mars? It seems that with the assets that we have now and that we have in the near term, that we could use your staged approach to go to the moon and go to Mars and Bill, Ed, Chris address that.

Chris McKay: Okay, let's briefly do that. Ed, maybe you could start with just a few quick comments and then Bill.

Ed Viesturs: Yeah, for us staging is critical because we have to -- not only put supplies at various camps, but it's also the process of acclimatization. So you need to take the time to go at various altitudes and then come down to recuperate and then slowly work to a higher altitude. So it's kind of a necessity in both aspects -- acclimatizing and also then getting your gear in place. Once acclimatized, though, I've developed a system now where we'll go very quickly and -- like you said in that big launch vehicle -- we'll carry everything that we need and in three days, we'll do what normally takes two months. We'll climb moving everything with us and then go to the summit. That's riskier, but it's also faster because you're spending less time in a dangerous environment. So I think the trade-off is worth it. I'd rather climb faster without the series of camps behind me, but I need to do that initially to acclimatize.

Chris McKay: Bill, you want to give us the downward view of the same thing?

Bill Stone: Well, you know, I think David rather unfairly branded what we do as risky. It's no more risky than being a test pilot, okay? [Laughter]

Chris McKay: And your point?

Bill Stone: No, I mean, you can control the risks. There's one thing that you can't control, but you can prepare for, and that's the weather, okay? And we're going to have that kind of phenomenology wherever we go, whether it's a [fuller] storm or whether it's, you know, a big storm that comes in on Everest or whether it's a hurricane that dumps ten inches of rain over the [Watwa] plateau and you get a 20-foot high rise in the water wherever you're at. I have friends who have bolted their way 30 meters up a canyon wall as the water rose behind them and hung from rock bolts for 32 hours waiting for it to go down. They were prepared, you know. Yes, they were in a dangerous place, but they had their act together. Let me extend this to space, okay, because I have actually put a lot of thought into this. I've designed spacecraft, I've designed reaction control systems, things like that. Given what you've seen here, okay, and this stuff -- one of the things that you don't understand here is that we did have complete control over the situations where we were -- even the weather. All of our camps are selected to be above the water. The way the ropes were rigged -- all of that stuff was high reliability levels that we had everybody trained on the team to know when to replace things. We even had ways to get out if a rope broke. We had all these things covered.

Now, if you switch to trying to think about what are you going to do if you're trying to get to the moon, okay, which is the next logical target for us to get back to here and prove that we can live off this planet. The first thing you've got to say is, all right, how are you going to get to LEO, right? And there's only so many ways that we can do that right now. You've seen what I do. If you were to say to me, "Would you fly the shuttle?" or something like that, then I'd have to say, "I have to think very carefully about that, because it does not meet my criteria for having an abort mode at any point in the trajectory. You didn't pay me to come out here to give you sweet talk so I'm going to talk to you straight. The last time we had a launch vehicle that met those criteria is when these gentlemen were flying. Why on earth have we not done that now? That's just my personal impression, such that if I was going to try to put something up there we'd probably be using ELDs with abort modes to get us out of there into LEO. Beyond that, you're into the issue of: how survivable are your vehicles? You need to be thinking in terms of propulsion, life support, and everything else.

You guys are great at this. NASA is a technological gem on this planet. But unfortunately, we don't have enough true expeditionarios here, as we say down in Mexico -- true expeditionary people who think: "Two years from now we're going to plan an expedition and we're going to do it." The way we think around here these days is: "We can develop these technologies and maybe 20 years from now we'll be back on the moon." That's too late. That's too late. You've got to get there now and learn from the frontier, just the way we've been doing underground here. Those places were unexplored 12 years ago. We've built technology to go there. Given the enormous resources around here there is no reason that we can't be back on the moon within five to seven years, max.

Questioner: If the moon is where you want to go.

Bill Stone: There you go! [Applause]

Dale Anderson: I want to go back to your question about staging, which was doing things in steps. I think a lot of the issue there is knowing what the stages ought to be. I remember once getting a lot of flack -- we were going to the Antarctic to do diving under the ice with Dale. I put in travel orders to go to Key West -- that was our staging spot. We were going to do training for ice diving in Key West.

Now, maybe you could argue that was a good place to go to stage the Antarctic or maybe you could argue that it wasn't necessary. So when we plan anything, any expedition, I like to think: what is our goal? What are we really trying to do? What's the driver at the long end? And then what do we have to do to get there? If you look at the way Apollo worked, as I understand it, it was very much that way -- as we heard this morning. You want to go to the moon so you need to develop docking, you need to demonstrated orbital -- that you can stay in a spacecraft and so on. Take something like Gemini -- it was a requirements-driven program: "If you want to go to the moon you're going to have to do this first." It wasn't: "Let's do Gemini and see where it leads" or some nebulous concept that somehow if we develop these things a mission to the moon will miraculously appear from the pieces.

And I think as we think ahead to an exploration program we have to do the same thing: where do we really want to go, and then what are the pieces that lead us there? And I think that's also what Bill was saying. So your question is a very good one and I think exploration on Earth and people that plan expeditions on Earth -- the logic that they approach can be applied, but the answer is not so easy to come by.

Chris McKay: Okay -- the next question is right here. Maybe someone can address my challenge to pick up the case for robots, but probably not you!

Skip Reiber: Well, maybe I will! I'm Skip Reiber from Goddard Space Flight Center, a scientist-type as opposed to a program manager, which seems to have been commented upon today.

Chris McKay: Derisively, I might add!

Skip Reiber: It seems to me that over the years NASA has been very ambivalent about the tying together of people in space and science. Back in the '60s getting people up there seemed to be something done for its own sake. Putting somebody on the moon was done for its own sake. Then in the '70s and up to maybe the '90s we started getting into a mode where we were trying to be sold on the fact that people had to be there to do the science better. And it never appeared to me that that was the case -- that it was a selling job to justify getting people in space, for the most part.

And I guess my question now is: do you think that the public, Congress, and the media are ready to do real people in space as opposed to trying to do the science with robotics? My personal feeling is much of the science could be done better with robotics but we're not going in that direction right now.

Chris McKay: Okay. That's a good start to the case for robots, I think. And I think we need to put that case out there as part of the complete discussion because one answer to the risks is don't send people. You avoid the risks. If we go back to Dale's categorization of risks -- mission risk, personal risk, and team risk -- what you eliminate is the personal risk and team risk by not sending people. Certainly, when Steve Squyres did the MER mission there was risk. But no one's life was at stake on Mars -- it was just a programmatic risk, a science risk. The worst case that could happen was that Steve would have wasted seven years of his life and no publications would have come out of it. Steve might have felt that that was a disaster, but no one would have gotten killed over it.

So I think the case where we think about risk -- we can't just assume that means that humans are in the loop by definition and therefore we figure out how to deal with the risk with humans. We have to step back once and say: are humans even an essential part of the program, of the loop, or do we try to do science by robotics?

So now we've made the case for robots. Let's let the panel and the audience react to that case. David is going to add to that. We've got a momentum going here!

David Roberts: No, I actually would strongly believe that robots are the answer. And I think it's probably my father's influence, because he told me years ago as an astronomer that there's no way we're ever going to get very far in human terms in space, so the future is going to be robotic. And I found the Mars Rover landings more gripping than the original moon landings, human-equipped moon landings. And I would say that the

Hubble Telescope was far more important and exciting to me than any manned travel in space.

And I think that for the first time in history maybe we can actually make the emotional and psychological investment in machine discovery -- as we're also doing in the deep sea -- in lieu of the conquistador going out there and doing it himself.

Chris McKay: Okay. Penny, I'm hoping you'll take the contrary view!

Penny Boston: You know I am!

Chris McKay: What a surprise!

Penny Boston: I think that there is no dichotomy between robotic and human exploration. I think much ado is made out of that. They're obviously context-dependent. There are strong reasons why we're interested in human exploration beyond simply the scientific function. And I disagree that now or any time in the near future, or even the mid-term future, we can design a robotic instrument that can have the capabilities of the tremendous flexibility that a field scientist can have.

However, that being said, I am a great fan of robotics missions. I love robots -- I wish I had whole fleets of them myself. I'm trying to get MIT and JPL to build whole fleets of them -- because they're a tool. They're not a viable life form at this point. It's not as if we're going to -- at this point it's not as if we're going to send robots or people. They are obviously complementary to the whole scientific process. But science is fundamentally a human enterprise, and the value of science is fundamentally to us as humans. And so therefore cutting us entirely out of the loop I think is inexcusable.

And so wherever in the solar system we can send people where it makes sense and where people can significantly contribute to that -- and one of the things that they have to contribute to that is that perception of the human experience of exploration -- then I think that we should endeavor to do that, and save the robots to be our helpers and to go places where we can't go, to go first. And even on Earth where we're exploring certain caves where we have tiny channels that we can't get into, even micro-robotic devices there would greatly enrich our scientific exploration.

Chris McKay: Well said. Dale and then Nathalie can respond to the same question and then we'll take a question here from the woman in black, and then Jim [Garth]. Dale?

Dale Anderson: Briefly, I was just going to actually completely agree. I think it's a mix; it's not an either/or case. When robotics are required they should do the job, and when people have the capability to go to those places people should be in the loop.

I've used both robotics and going there myself, and I have to admit: I've been underwater with robotics, for example, while people at Ames have been diving with me virtually via that robotic device. That's a great way to share your experience in a remote location with a greater population. But it's not an either/or thing -- it's just the right tool for the right place at the right time.

Chris McKay: Nathalie, could you add a little to that? And then we'll go back to general questions.

Nathalie Cabrol: I'm supporting both Dale's and Penny's views because I've been putting together in the field an astronaut and a robot. And neither are always best at what, but how they complement each other. And for exploring a planet, the human being will bring in his immediate background and an understanding of what’s around him, which a robot cannot do now and will not be able to do in a long time. But by the same token, the robot does not care too much about the environment. Is it cold is it hot, is there lots of UV radiation. If there is an opportunity, they just don’t care, they can last a long time at the surface, and long periods of time. Together they are almost an invincible team, but I would go a little step farther than that. I would say that, no matter what we think about it, exploration is within our genes. This is part of the evolution, where part of evolution is right there, in us. We wouldn’t be there if we wouldn’t have been taking risks, and going one place to another and exploring diverse habitat. And another planet is just the next frontier for us; there will be farther frontiers than that, and just thinking that robots can do that for us, just putting our species in a very [unintelligible].

Chris McKay: Donna, did you want to make a comment on this? Okay, we'll get to you then, in turn. Question right here.

Becky Ramsey: Hi, I'm Becky Ramsey, I'm from NASA headquarters, and I have to say that human versus robot, I have to come down on the human side, because I want to go. Yeah, and that actually leads into an issue I want to raise. I want to touch on something that we talked about earlier this morning, and that's individual versus government exploration. To bring up the example from this morning, Burt Rattan ready to launch in just a couple of days here. What he's done is private financing, small group, hand-picked people. And that seems to be very similar to what you all do, whether it's individual, or privately financed or government financed, even if it's a direct NASA project. What you do seems to be very small, one person, five people, even a hundred and fifty people, when you compare that to my colleague and I who work in the same building and have not met before today. That's very different, you know everybody on your team, and you're getting a lot further out there than we are. Is there something to be said for that -- can we do this? Can government do this, can an agency like NASA do in space what you have managed to do here on earth, or do we need to find a different way, and look at smaller, more team-focused models to do this?

Chris McKay: That's a really good question and when we look beyond earth orbit to distant destinations like Mars, the question becomes more pressing, because those teams have to be, by light travel time requirements, more and more autonomous, and less dependent on remote control from mission control. Anybody want to address that, comment on that? Penny and Bill, think of an answer too.

Penny Boston: Okay, I'm thinking real hard, that's a really serious question. Obviously you know people are wrestling with. The kinds of expeditionary things that we do are very small compared to a full-on mission to another planet. Therefore the sheer number of people involved is so large in order to pull off a mission like that. In some ways, I'm not entirely sure that a lot of our experience in these smaller units is directly applicable. Because by force you have to involve so many more people, and the level of planning complexity far exceeds anything that any of us do. So the question is can you do that in a governmental environment? Well, I think NASA is doing it in a governmental environment. And I don't see why fundamentally that transition from the kinds of missions that we're doing now can't be applied to also incorporate serious meaningful human exploration, plus, an ongoing program. I don't see that it's not possible, with the caveat that for certain applications, perhaps small companies are better, for certain limited things. Burt Rattan is also not doing NASA. He is not doing NASA. He is not doing NASA in a can, basically. He is doing a very different scale of things than NASA has to worry about.

Chris McKay: Okay, I'm going to skip Bill's answer, because I think Penny hit the nail on the head, so we're going on to the next question, which is Jim Garvin, then we'll go there and then Squyres, and the [Lempe].

Jim Garvin: Well, thanks Chris, Jim Garvin, NASA headquarters, Moon Mars. I wanted to comment and then address an issue to the panel and everyone about the robot/human, whatever you want to call it, dichotomy, because I don't think it is one, and I think we have to pay attention to the great observations you all made. Because in our history of space exploration, it was the robots that did the reconnaissance, the advance planning, that let the humans, like the great courageous heroes today do the work. And I would submit to you that it was then, the humans back on earth, and Apollo XVII, and Apollo -- all them -- continuing the work of them. So it's that partnership that's important. And in many of the cases you've talked about robotic reconnaissance wasn't needed to open the frontier. The humans could do that on the fly to allow us to do that. We don't have that luxury.

I would dare say I wouldn't want any of you brave people to go to the surface of Venus for the first time. It's probably better for our robot friends to do that, and today as we think about Mars I would submit that we're just learning through the rovers now Steve will talk about, to what we're planning in the future, to do in the reconnaissance necessary to go to those sweet spots that you are now at here on earth, in the unique ways that you're doing. And I think that that's blend. So as that stage goes, then the humans become important on-site to do that kind of work. And I always marvel, if we think about this dichotomy, and I ask you all to think about it, in the gift that keeps giving theory, that I think that is the case when we look at the samples brought back from the moon from the Apollo mission. These multi-kilograms, each one itself a mini-universe for robotics and people to work together with here, to understand that world. Imagine that anywhere we go, whether it be on earth or beyond.

So I look at it as the reconnaissance that's important and today a lot of that reconnaissance is better done on Mars, on the Moon, on Venus, way out where the origins of the universe or whatever, by the machine. The question is here on earth, how can we amplify your experiences, in these unique environments, unique settings, to better train us to use that reconnaissance to make the choices of now we have the tactical decision to put humans on-site because we need to, because it's in our gene pool, or it's necessary, it makes us better samplers. That's the question that I think this risk conference is treating, and I think at times that unfortunately comes down to the ugly word programmatic cost. Where is the timing of that benefit?

Chris McKay: Okay, good comment. Let's go to Keith for another comment or a question.

Keith: Okay, you were trying to pick a food fight a few minutes ago, and I love a food fight.

Chris McKay: I'm trying to claim my role as moderator to stir the conversation

Keith: Well in that case, I'll take that on-

Chris McKay: You can always fire the moderator, you know.

Keith: Whether it's robots or humans, in essence it comes down to us going out there, whether we do it first or second or in tandem, and I guess one observation to make to throw a little raw meat into this argument is it's all about what we as a culture are looking to do. When is the last time somebody threw a ticker-tape parade for a robot for doing something in space? When's the last time we all cried at a national funeral when a robot didn't work? Just an observation.

Chris McKay: Let's go to Donna Roberts, since I skipped her in the sequence. Sorry Donna, you had your hand up for a while ago, and then we'll come back to you, Steve.

Donna Roberts: I'm Donna Roberts, of the University of California San Francisco medical center, and my question is with humans and extreme environments, and safety is utmost, and pushing physical capabilities, what is necessary for medicine? Should it be a first aid kit, should it be medicine, should doctors be there, what kind of diagnostic and therapeutic capabilities should we have?

Chris McKay: Can we get some quick answer? Penny, Bill, we'll let you answer this one.

Bill Stone: You just got to get me fired up. If you started to think -- and you asked me, go plan an expedition to Shackelton Crater or something, who would you take? And I've thought about this, the answer is, number one, you bet, you're going to have a physician. He also would probably be co-trained in dentistry. You may have to have a back-up to that person as well who is perhaps co-trained in something else. We try to have a physician on every project that I have ever run. It's just too good a thing to have at base camp, whether they're out in front or not. It's one of those contingency things you have to think about when you're talking about long-duration projects. Okay, if you're at a place where you're only an hour and a half or in orbit reparee, before you can drop back in, like you are right now at the space station, it's not such a critical thing, provided you have on-demand re-entry. You're not going to have that on the moon. So yeah, you will have to have physicians out there, no question about it. The question is what skills should they have? And if I had to pick two I would say emergency room experience and dentistry. The rest can be actually done through tele-support from the ground. You can go on from there with all the other skills as well.

Chris McKay: Isn't that something -- you go to Mars so you can visit the dentist.

[Laughter]

That's why we need to send humans. Robots don't need dentists.

[Laughter]

We have a question here, and then we'll get to Steve. If you can pass the mike to Steve Squyres. A question here?

Scott McGuinnes: This is for Doctor Stone. Or actually . . . [Scott McGuinness], submariner, student here. Doctor Stone, as a diver, I was looking at your videos, and you go deep into these caves, and you dive. You don't have -- US Navy tables don't take this into consideration, your depth already? The Haldanian model doesn't take that into consideration. So, my question is, how did you mitigate the risk of DCI or decompression illness, or those risks, and how can that compare to the risk of radiation, GCR and all that for astronauts going to Mars? It seems like one of NASA's larger problems is how do we mitigate the radiation hazards of deep space.

Bill Stone: The decompression analogy, I suppose, is not as big an issue -- at least from my standpoint. Mike Gernhardt and I could probably debate this for another eight to ten hours. The answer to your question is, those life support devices that you saw there had triple parallel redundant decompression engines running in real time. They were written in accordance with what we had known to be conservative, and we drew a line that was about 15 percent above that. It took into account real time oxygen concentration and then fed that through a head-up display. What that meant in terms of an operational situation is that when a yellow light would come on while you were in the middle of a dive, it would mean that you had to be considering what your decompression scenario was going to be like when you started to come back up. When we got to those stages, we would automatically boost the oxygen concentration such that we were far in excess of what would be required for a conservative decompression. We have never had the bends hit on any of those projects, even though we're diving at altitude. All of those things have triplex digital depth sensors that are also sensing atmospheric pressure at the altitude at which we were diving. That was all really taken care of pretty conservatively.

As far as I understand it, and I don't profess to be an expert at this, the issue of space radiation is really one of shielding and stochastic analysis of what the radiation environments are. You don't want to be out there on the 11-year cycle. If I remember correctly, there were some analyses that were done in the 70s that indicate -- and I can't remember -- maybe Jim knows -- that between two of the Apollo flights there was an anomaly that if you had been flying during that time, there may have been some serious exposure issues. To me, that for deep space is actually something you can mitigate through the series of water barriers and things like that. I believe it's ten centimeters of water is sufficient to stop most of that. If you check throughout the right areas and within NASA, and probably [JSC] has people in this, you'll find the answers to those. I don't consider that anything more than an engineering problem.

Chris McKay: Steve Squyres. Introduce yourself.

Steve Squyres: Steve Squyres, Cornell University. I want to return briefly to an issue that was raised earlier about how small organizations seem to be able to sometimes accomplish more. If you look at what somebody like Ed Viesturs does or what Bill Stone does -- If you look at a group like Burt Rattan and what they are accomplishing there. It's easy to look at an organization like that and say, boy, they're lean, they're compact, they're able to get the job done. You then look at larger government agencies, and you sense a difficulty there. But I think there is a wonderful counterexample. The wonderful counterexample was what Jim Lovell talked about this morning. It was Apollo.

You look at Apollo, and you look at Gemini, and you look at Mercury, you look at what was accomplished in those days, and it was a huge organization. It was in some ways bigger than the NASA of today. Yet, they got things done.

When I look at that, what strikes me is that there was a common thread through those organizations, and that is that they knew exactly what it was they were trying to do. The level-one requirement for Apollo was stated in one sentence by the President. When Ed goes up a mountain, he knows what his level-one requirements are. It is very, very clearly stated. If you have a common goal that is clearly understood by everybody in your organization, I don't think it matters how big the organization is.

Chris McKay: Good point, Steve. We have five minutes left. We have time for two questions: one here and then one there . . .

Eugene Roddenberry: Hello.

Chris McKay: And then the camera gets turned off, and it's free-for-all.

[Laughter]

Eugene Roddenberry: Hi. My name is Eugene Roddenberry. My father actually created Star Trek, and working in the industry, I have met a lot of people who have been inspired by the show. It's completely different to work in entertainment, but the people who have been inspired have inspired me to look around the world and meet individuals like yourselves. I think you guys have shown that humanity is able to overcome adversities as well as many of the people who work in this room at NASA. And the fact that that inspires other scientists and other people in the field to reach for the stars or down to the depths of the ocean, I think it goes beyond that. You guys actually inspire -- you guys inspire fans who have disabilities to overcome those disabilities -- people who are in relationships -- people who have everyday risks that they need to take. I think the fact that they see that humanity can take these huge leaps -- these steps beyond -- I think it goes down to every individual on this planet from around the world when they see what you guys do and what you guys do in the room, it really shows that we are capable of taking those next steps. It is very impressive. I just wanted to say thank you to everyone. It's very exciting.

Chris McKay: Thanks for your comments. The next time you send a message to your Dad, thank him for me. I was one of those Trekkies that got inspired to seek out new worlds and all that stuff from watching the show. It's the only television I watched. Larry?

Larry Lemke: Larry Lemke, NASA Ames. I would like to actually follow up on Steve's comment and some others on this whole question of how do you take the lesson from small-scale exploration and put it into a bigger context. I agree with Steve. I actually don't think that size of the organization per se is the issue. If you look at the participants on the panel, one of the sort of obvious characteristics that they share is that not only do they plan the expeditions, they do the expeditions. I am reminded of that comment that there's nothing like the prospect of being hanged in the morning to concentrate your efforts.

[Laughter]

If you look at the way NASA typically plans a large human exploration project, it is sort of notable that the people who are making the decisions very often do not really have to experience the personal consequences of those decisions. I think if that were to change, then the results might change as well.

Chris McKay: So you're saying we should send a NASA administrator to Mars?

[Laughter]

Is that a way of interpreting what you said?

Larry Lemke: Or have the NASA administrator to actually design the vehicle. Get the opportunity to fly in what you design.

Chris McKay: We actually have a few more minutes. One last last question. Right down here. Kathleen, could you bring the mike down here? And that will be actually the last last question.

Bruce: Bruce [unintelligible], two shuttle flights. We get back to the human versus robot trade-off. Currently when you are looking at a Mars mission, you're looking at speed of light transit times, round trip up to 40 minutes. So obviously its gonna be hours when you get out to the vicinity of Jupiter and Saturn. The thing that seems to be missing is the decision-making ability -- the refined decision-making ability -- the ability to adapt to unforeseen situations, to recognize something that you haven't been programmed to recognize. I assume that eventually computer science will advance to the point where we can send androids. I wonder if anyone would like to comment to the speed of light transit time as a factor in trading off between humans and robots.

Chris McKay: That's a good point. Maybe I ought to add to that question, how will that influence the autonomy of an expedition on Mars versus the autonomy of, say, a shuttle or a station where there is virtually no delay -- see them as being more autonomous or not. Maybe we could just -- does anybody want to approach that? Penny? Dale?

Penny Boston: Yes. I think that it's a return to some of this historical stuff that Jack Stuster was talking about this morning: the fact that those expeditions, before there was the kinds of instantaneous communication that we all have, were able to operate and do what they needed to do. We seem to somehow believe now that we cannot do that any more. I think that a different kind of planning within NASA perhaps will be necessary to take us back to some elements of that kind of self-contained expedition.

Chris McKay: Okay. We're running out of time. What I would like to do is wrap it up there first by thanking all of our panelists, both for the heroic expeditions they go on and the beautiful pictures they showed us of those expeditions. I want to thank the audience for the discussion, and the different points of view.

[Applause]

Thanks a lot. I think now the session is over, but we will have some opportunity for informal discussion. You can ask them, How cold was the water underneath that ice?

[Music]